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GROUP

NY DATA CENTER
ENERGY BENCHMARKING AND CASE STUDY

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I. Executive Summary

The New York State Energy Research and Development Authority (NYSERDA) sponsored this project to study energy use in a New York data center. The study focuses on energy efficiency issues in the selected data center, determines energy end use, and looks for energy efficiency opportunities.

A goal of this project was to provide the actual energy intensity in an operating data center in New York. In addition a particular focus of the study was to study the control systems for various energy intensive facility systems.

This information together with other studies will provide insight into the distribution of electrical power with the data center and the overall electrical demand for data center facilities. Energy benchmark data for a sufficient number of data centers will also eventually help to identify current best practices, and determine efficiency and reliability improvement areas. Additional case studies benchmarking energy use in California data centers were performed. These projects are developing a more robust set of benchmarks and efficiency recommendations.

The facility selected for the study was a mixed-use facility, with several data center areas distributed throughout two buildings. Two large main buildings were in excess of 415,000 sq. ft. and also contained a large amount of office space, a cafeteria, and other support spaces. Chilled water was provided by a decentralized chilled water plant consisting of five chillers of varying sizes and ages, tied to a centralized condenser water system. Chilled water was pumped into a common header for distribution throughout the entire facility. Base load chilled water requirements were met using a relatively new 1,000 ton chiller. The new chiller was assumed to be the most efficient (the lowest kW/ton of chilled water), but this was not verified by direct measurement during this study. Due to the size and complexity of the heating, chilled water, and other building infrastructure systems serving the entire complex, they were beyond the scope of this study. The main interest focused on electrical power consumption within the defined data center area.

The data centers within the selected facility contained a large variety of computing equipment for various uses. The facility is mainly used for data recovery purposes involving multiple customers with a wide range of computing equipment. As such, the operations may not have been as uniform as some other types of data centers, such as web hosting or dedicated data processing. Through investigation and from power use profiles collected in our measurements, the data recovery activity was observed to cause variation in power usage not typically encountered in other data centers.

Figure 1 is a representative time plot showing some variation in electrical load. The site team did not attempt to determine the cause of variations in computing loads.

Energy metrics were developed to determine and track energy intensity for the overall facility and for the computing space. These metrics allow comparison to other datacenters and provide indicators of the performance of individual systems and components.

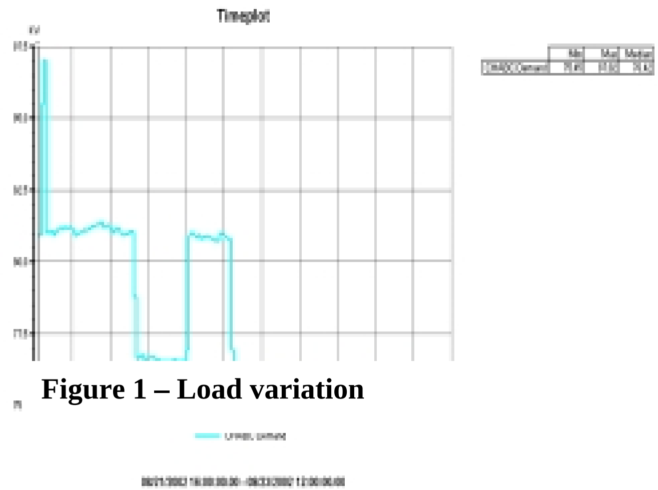


Figure 1 – Load variation

The benchmarks obtained in this study are useful to the host facility for several purposes:

- ♦ Providing a baseline to track performance over time
- ♦ Identifying the most energy intensive systems and components
- ♦ Uncovering operating and maintenance problems
- ♦ Finding energy and reliability operating and retrofit improvement opportunities
- ♦ Comparing performance to benchmarks observed elsewhere
- ♦ Determining energy intensity trends in computing equipment over time
- ♦ Establishing efficiency improvement goals based upon benchmark information
- ♦ Establishing operating and design targets for future projects

As more robust benchmark data is available (a statistically significant set of data), it is expected that best practices will emerge. In addition, the host site, being part of a large national firm, should be able to compare its performance to its other data center facilities within the firm as well as to the data centers benchmarked by LBNL or others. This may provide awareness of opportunities for continual improvement.

The host site proved to be a difficult case study for several reasons. The facility, being older and modified by years of additions and renovations provided a challenge to isolating areas/systems of interest. A significant amount of office space and other support spaces made isolation of just the data center systems and space a difficult task. In addition, information that is often provided in building information and management systems in more modern facilities was not readily available. The mixed use of the facility, combined with complex systems (such as the chilled water system) that were added to over the life of the building, necessitated taking a simplified approach to evaluating systems. To obtain useful data at a more detailed level, the measurement team defined a smaller "control volume" to study the energy end-use in one representative computing area. The study was further constrained by the fact that the data collection team had difficulty obtaining site information due to staff reassignment at the facility. Nonetheless, useful data and observations were eventually obtained.

The primary area of interest was the HVAC system serving the data center areas, but the study also included other data, such as other typical office loads where the data was available or easily obtainable. Whole facility energy use was obtained and then systems serving the smaller control volume were evaluated to as detailed a level as practical. Unfortunately, the original design information was not available due to the age and history of the facility.

The accuracy and completeness of data varies, based upon the measurement methods, access, and ease of measurement. Nonetheless, the data is sufficiently accurate to determine energy intensities and is useful for other observations concerning the facility.

The energy intensity due to the computing equipment in a defined area of the data center (control volume) was calculated based in part upon measured power use along with simplifying assumptions. The intensity values are useful for trending electrical load growth as computing equipment evolves and, in the case of this facility, as computing equipment changes to satisfy customer needs. To quantify the maximum electrical intensity if the center were full (using the current mix of computing equipment) a qualitative assessment of the percent occupied was made (or how full the data center was). A comparison to benchmark data from other data centers in the study is provided in figure 2. In this figure, the load density due to only the computer load is plotted and averaged approximately 25 W/sf. This case study is facility 10 on the graph.

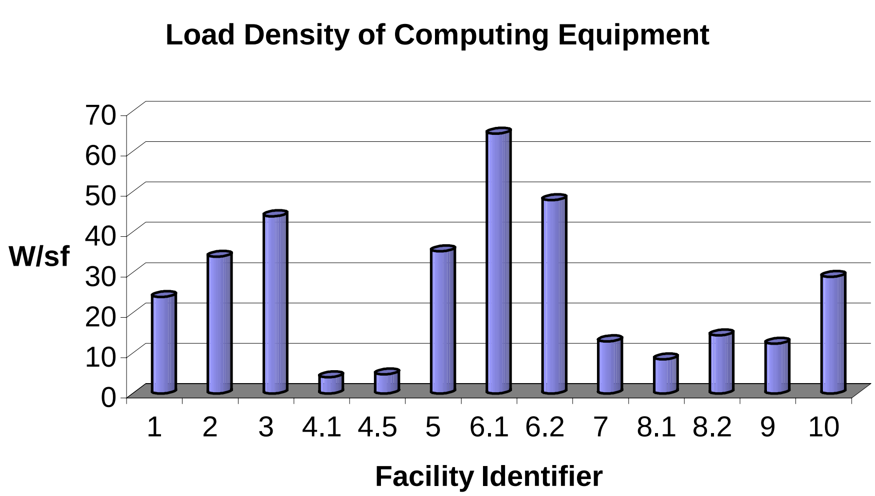


Figure 2 Measured Computer Load Density

A number of observations for possible efficiency improvements or further study for this facility are provided in this report. The observations were not meant to be in response to a comprehensive energy audit, but rather represented specific opportunities for improvement, for further study, or for use in future modifications or new construction.

II. Introduction

In order to gain a better understanding of the energy requirements associated with the increasing use and centralization of data processing equipment in specialized facilities known as "Data Centers" the New York State Electric Research and Development Association (NYSERDA) commissioned Lawrence Berkley National Laboratory (LBNL) to conduct a study of a Data Center in New York to determine the current operating loads and to identify energy efficiency opportunity in the facility. A data center facility volunteered their site in lower New York state for this study. To assist in collecting site data and obtaining measured electrical use for the facility, LBNL contracted with Syska and Hennessy, a data center design firm located in New York City.

III. Site Overview

A multi-national corporation with a data center in Orange County, NY volunteered to participate in the study. This location is a mixed-use facility consisting of office space as well as computing space. One of the functions of the facility is to provide customers with a facility to enable processing and management for disaster recovery. In this regard, the host site or the customer may provide computing equipment. As a result, the mix of computing equipment is diverse and changes frequently. The facility includes two buildings totaling 415,000 square feet (ft^2). Of this total 119,000 ft^2 is classified as technical space (raised floor) whose primary function is the support of data processing equipment. The remaining space is office, cafeteria, and other support space (equipment rooms, supply storage, etc.)

Some general information regarding the function and capacities of this facility are as follows:

- The two main buildings were constructed in 1972 and 1982 respectively. Additions and renovations occurred over the life of the buildings. A central chilled water central plant provides cooling for the campus. Cooling for the office spaces is supplied from the same system as the data center so that isolating the cooling for the data center spaces only is very difficult.
- Two Redundant 69kV Electrical Feeds/facility draws approximately 2800 kW
- Two Independent On-site Substations for Site Service – 10.5 MVA each
- Three 7.5MW Gas Turbine Back Up Electrical Generators

- UPS Systems of 1500 KVA and 3000 KVA for Buildings 001 and 002 respectfully

- Distributed Chiller Plant with 3000 ton capacity –

    - Chiller (electric) capacity of 3400 tons and

    - Cooling tower capacity of 3000 tons.

    - Decentralized chilled water plant consisting of five chillers of varying sizes and ages, tied to a centralized condenser water system.

    - Chilled water pumped into common header for distribution throughout the entire facility.

    - Base load met using newer 1000 ton chiller.

- Central Boiler Plant with 800 BHP capacity (24,000#/hr) – 2 – 400 BHP Oil fired steam boilers

- 12,000 gallons of emergency water storage

- Energy Management Systems – Johnson Controls (METASYS); Westinghouse (INCOM LIGHTING)

- No natural gas service

IV. ENERGY USE

Historical Data

The host facility staff routinely tracks total facility electric use. This information was provided for the study. As expected, the total facility energy use is relatively constant. Monthly variations in electrical consumption are relatively small and are expected due to the nature of the facility (frequently adding or removing customers and their computing load), and due to weather variations affecting energy use in the larger non-critical areas of the facility (office space and cafeteria). Figure 3 below illustrates the total facility electrical energy use for a one-year period.

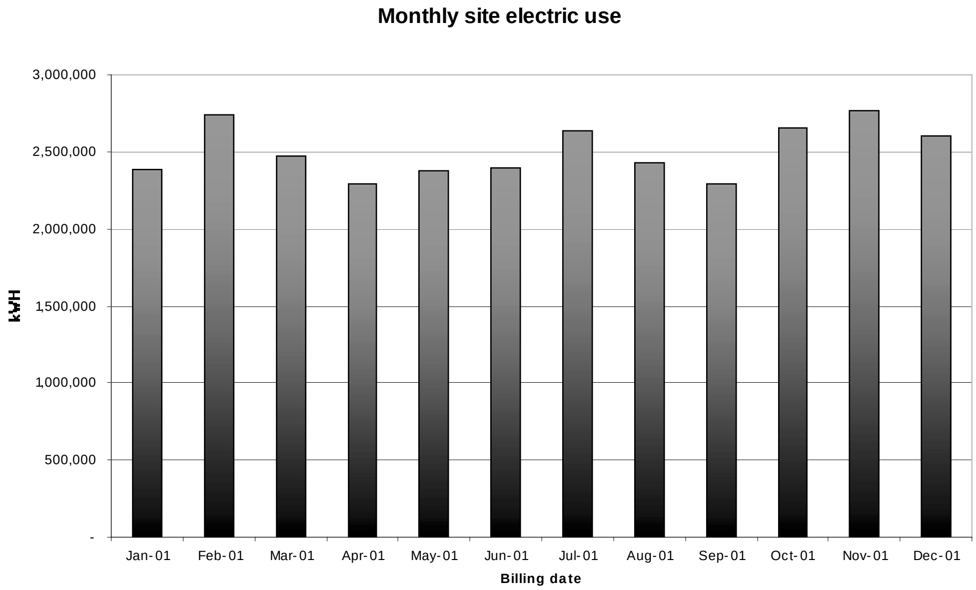


Figure 3 Monthly Electricity Use

Although the focus of this study was efficiency, we also observe that the average kW cost varied significantly probably due to demand charges. Figure 4 illustrates the variation in average electricity cost. This suggests that demand reduction strategies such as thermal storage, resetting temperature limits, use of free cooling, etc. may be attractive. Studying these opportunities, however, was beyond the scope of this study.

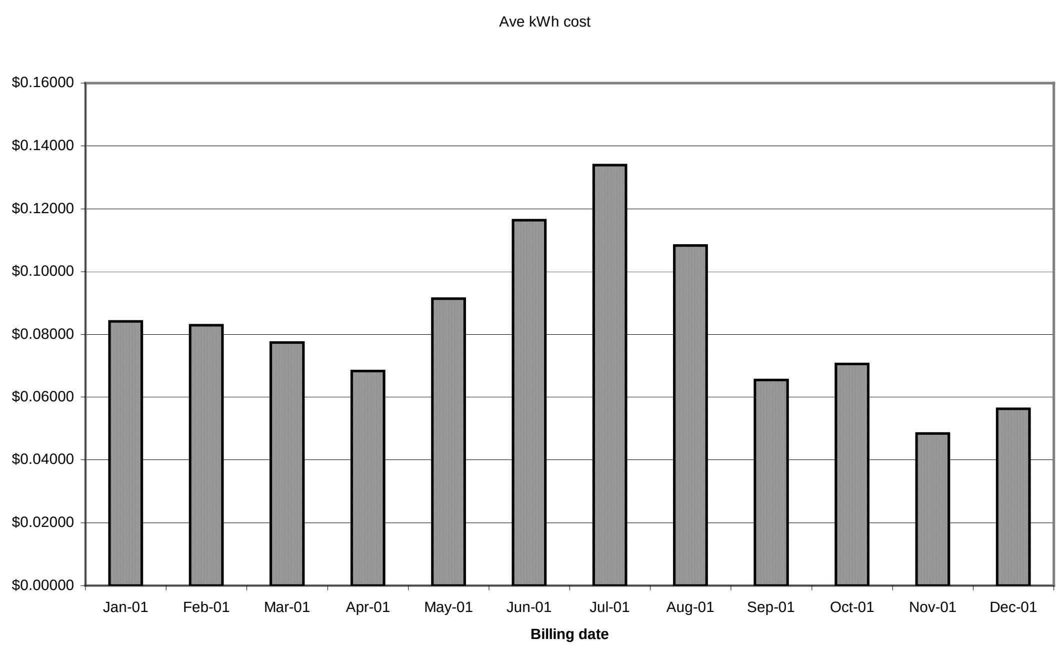


Figure 4 Average kWh cost

Further analysis of the historical data – calculating the energy intensity associated with the various facility spaces - shows that the data center computing equipment energy intensity overall is approximately 16 W/SF for the whole facility, and has been relatively constant. To calculate this metric, the total electricity serving the computing equipment is divided by the area of raised floor.

Figure 5 illustrates the energy intensities attributable to office space, infrastructure space, and UPS (computer equipment). Infrastructure (facility systems) energy intensity dramatically improved in 1998-1999 and has remained relatively constant since that time, as have the office loads. In this figure, the energy intensity is calculated based upon the respective square footage. Tables 1 and 2 present this detailed information by year.

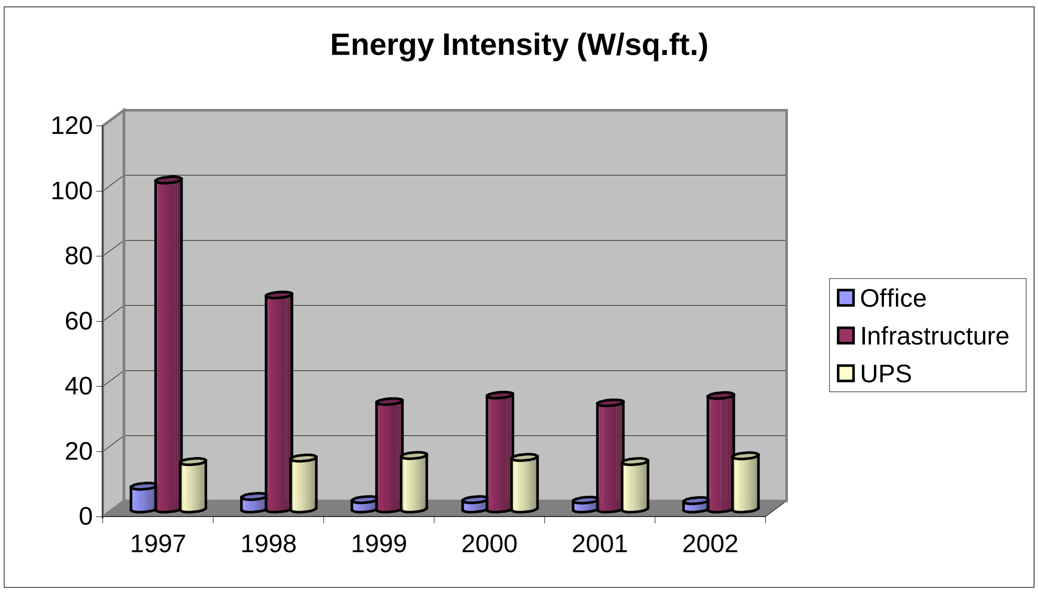


Figure 5 Facility energy intensity by end use for six years

Another useful breakdown is in the percentage of computing power consumption relative to the other facility loads and the relative square footage of each. This is illustrated in figure 6.

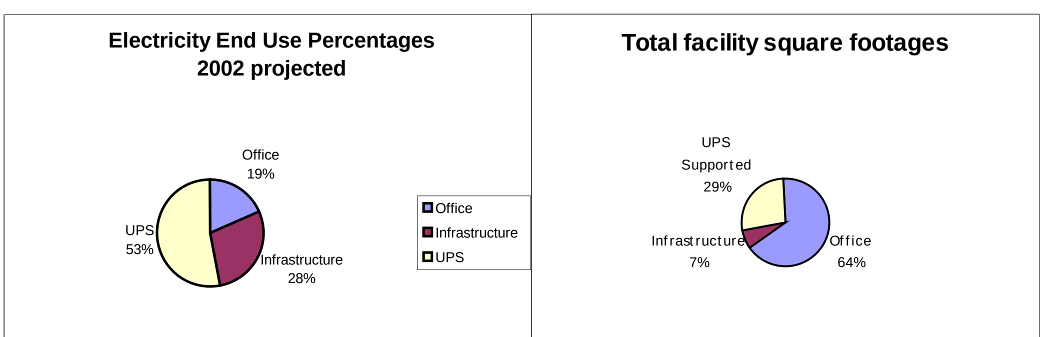


Figure 6 Percentages of UPS, Office and Infrastructure

This illustrates that approximately 53% of the facility electrical use is for computing equipment that occupies 29% of the facility.

Power Consumption (MWH and % of Total)									
	1997			1998			1999		
	MWH	% of Total	W/SF	MWH	% of Total	W/SF	MWH	% of Total	W/SF
Office Loads	16161.43	28%	6.93	8883.93	21%	3.81	6557.99	20%	2.81
Infrastructure Loads	26174.42	46%	100.95	17021.83	40%	65.65	8540.02	27%	32.94
UPS Loads	15127.33	26%	14.51	16249.87	39%	15.59	17076.66	53%	16.38
Total	57463.18	100%	15.81	42155.63	100%	11.60	32174.67	100%	8.85

Table 1 Facility power consumption 1997-1999

Power Consumption (MWH and % of Total)									
	2000			2001			2002(Annualized)		
	MWH	% of Total	W/SF	MWH	% of Total	W/SF	MWH	% of Total	W/SF
Office Loads	6514.45	20%	2.79	6257.81	21%	2.68	5940.97	19%	2.55
Infrastructure Loads	9048.16	28%	34.90	8439.68	28%	32.55	9022.83	28%	34.80
UPS Loads	16442.39	51%	15.77	15163.71	51%	14.55	16960.50	53%	16.27
Total	32005.00	100%	8.80	29861.19	100%	8.21	31924.30	100%	8.78
Building Space Distribution:									
Office Space				266400	Ft^2				
Infrastructure				29600	Ft^2				
Technical Space (UPS Supported)				119000	Ft^2				
Total				415000	Ft^2				

Table 2 Facility power consumption 2000-2002

The overall facility average and peak power density is provided in table 3 below. While these values are not particularly of interest when considering energy use of data center spaces alone, they are useful to the owner of a mixed-use facility such as this to trend overall energy changes due to mix of spaces, energy intensity of new computing equipment, mix of customer equipment, and efficiency of facility systems.

Calculated Facility Peak Electrical Power Density by Year						
	1997	1998	1999	2000	2001	2002
Facility Power Density (W/SF)	15.81	11.60	8.85	8.80	8.21	8.78
Avg Pwr Demand (KW)	6611	4764	3706	3652	2669	2832
Peak Pwr Demand (KW)	7993	6824	4727	6370	4193	4808
Calculated Peak Pwr Density (W/SF)	*19.12*	*16.62*	*11.29*	*15.34*	*12.90*	*18.10*

Table 3 Average and Peak facility energy intensity

Additionally, 2001 monthly energy use data provides insight into the amount of computing load compared to the total load. Figure 6 provides this data. The whole building load (demand) varied less than ± 3.3 % from the average during this period, confirming the relatively constant computing load. This small variation can be attributed to weather influence and changes in the amount of computing equipment.

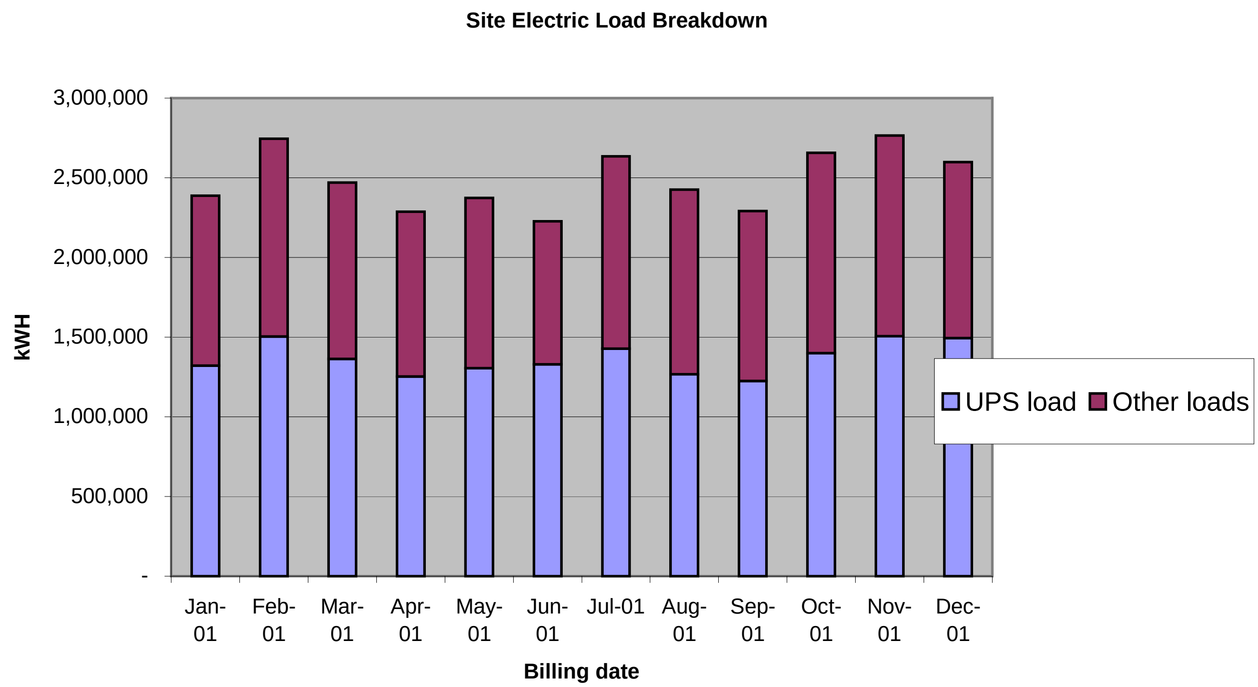


Figure 6 Computing Load vs total Load

The trends for energy end use can be seen in figure 7.

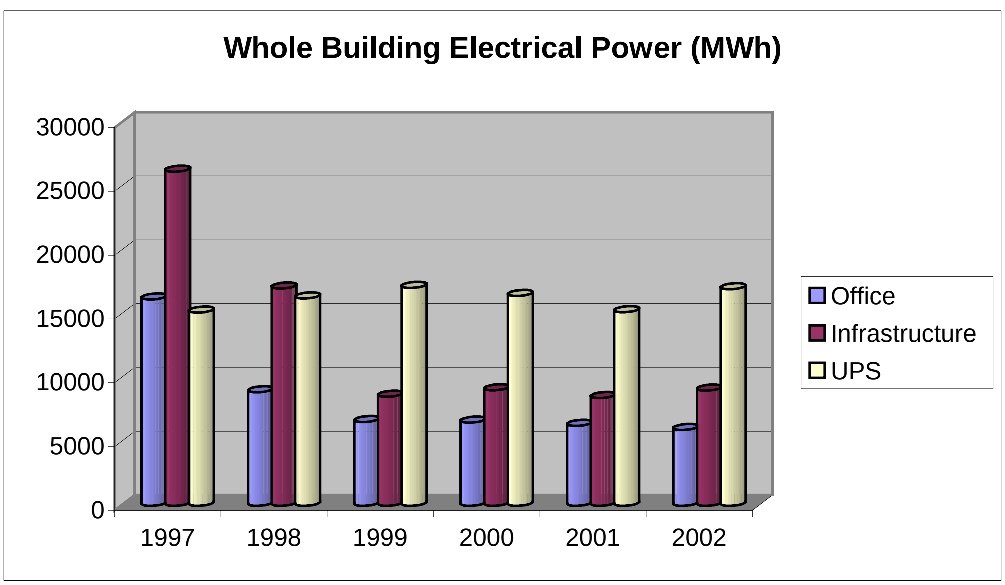


Figure 7 Whole building energy end use for six years

Approach for Data Center – Use of Control Volume

In order to study the energy use for the "data center" area, it was necessary to define a control volume that was manageable for this study. A theoretical control volume boundary was established for one area (a portion of the fourth floor of building 1). Energy flow into and out of the area could then be measured and/or approximated.

The area for study was determined after review of the facility plans and discussion with the facility staff. Isolation of a section of the top floor, which consists primarily of technical (data center) space, represented a good control volume to study.

A study of the facility drawings reveled that the upper floor is served by a single chilled water loop for cooling, and three primary electrical feeds. With this information a data collection plan was formulated. The goal was to measure the primary energy inputs into the control volume. A schematic diagram illustrates the chilled water system (figure 8) below:

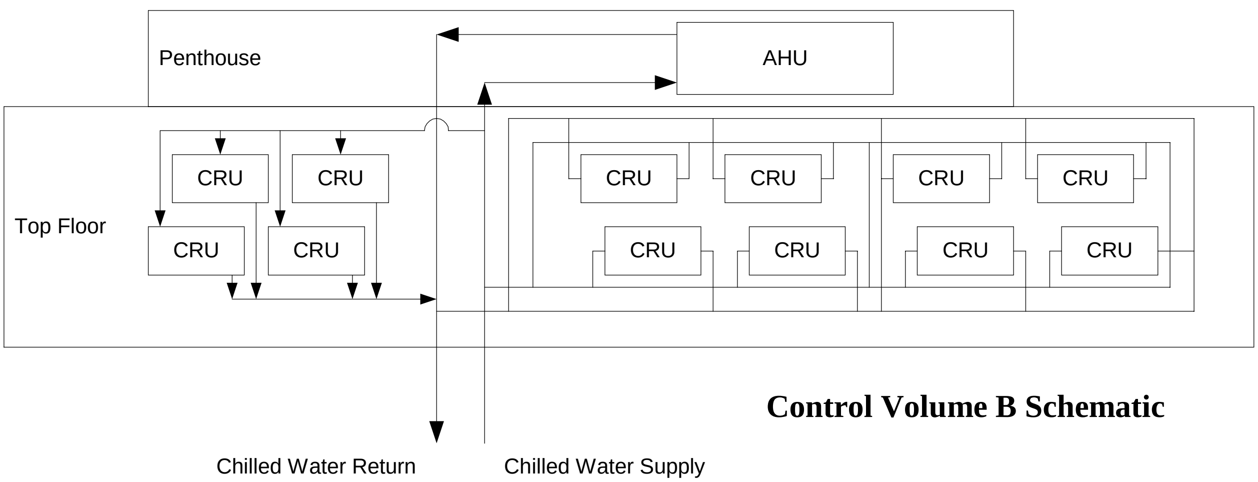


Figure 8 Chilled water system schematic drawing

The data collection effort was coordinated with the staff at the facility and on August 21, 2002 three Dranetz-BMI power analyzers were installed in addition to a Controlotron Energy Meter for measurement of the electrical and chilled water input into the control volume. These devices record the data electronically through the use of an on board computer and memory.

During the installation the team realized that the intended installation location for the Controlotron was not suitable for proper data collection due to lack of a suitable straight run of pipe. Changes in direction in the piping create turbulence, which interferes with the

Figure 9 Chilled Water Piping

operation of the ultrasonic transducers in the flow meter used to measure the fluid flow in the pipe.

An alternate location with sufficient straight piping was found, however this location did not capture all of the flow into the area. As a result some of the flow that supplies the space was not included in the measurement. The flow to the Penthouse AHU and the four units located to the left of the riser in figure 8 was not included in the measurement. This is discussed in more detail later in this report.

For the control volume, measurements were taken from August 21, 2002 through August 23, 2002 and additional data was obtained from facility staff prior to and following the site monitoring. For this time of year, there were no heating loads.

Figure 10 Data Collection

The data collected is presented in Appendix A, and the analysis of this data is described in the following section.

ANALYSIS

Assumptions

The following assumptions were made to simplify the analysis and to keep irregularities in the data from corrupting the results of the study.

1. Electrical power measured at each study point was consumed on the fourth floor or by equipment supporting the fourth floor.

2. The power meter installed at Load Center 6 is accurate.

3. The power measured on PDP 4-1 is split evenly between the third and fourth floors.

4. The power measured on Load Center 6 is distributed evenly throughout the fourth floor.

Calculations

The data obtained through the three Dranetz-BMI power analyzers (recording power demand and consumption) was analyzed and averaged for a consistent 24-hour period of study. The same analysis was performed on the meter readings from the GE Load Center meter, the data from that analysis is provided in the tables below.

Power Demand			
Measurement Point	Demand (kW)		
	Min	Median	Max
PDP 4-1	75.45	76.42	87.02
CDP 4-4	190.33	191.69	194.47
PNL C-7	34.02	34.65	36.02
Load Center 6	N/A		

Table 4 Data Center Power Demand

Power Consumption					
Measurement Point	Start Time	Finish Time	Total Measurement Time	kWH	Avg 24 Hour kWH
PDP 4-1	8/21/02 16:30	8/23/02 8:30	40:00:00	3138.4	1883.04
CDP 4-4	8/21/02 16:30	8/23/02 8:15	39:45:00	7680.5	4637.28
PNL C-7	8/21/02 15:30	8/23/02 8:30	41:00:00	1433.2	838.95
Load Center 6	8/21/02 15:45	8/23/02 9:00	41:15:00	10800	6283.64

Table 5 Power Consumption

Power Distribution Panel 4-1 (PDP 4-1) feeds the computer room air conditioning (CRAC) units on the third and fourth floors. We assume that the power measured is evenly split between these two floors. This assumption seems reasonable due to the similarity in floor area. Based on this assumption, the measured power for an average twenty-four hour period by the 4th floor data center CRAC units is 941.5 kWH. This is the power necessary to power the fans and controls on the units. Energy to supply chilled water is not included here since its supply is from the central chilled water system.

Computer Distribution Panel 4-4 (CDP 4-4) supplies UPS power to the Power Distribution Units (PDU's) located in the fourth floor data center area. All of this power supplies computer equipment located in the data center area. For an average twenty-four hour period the measured power consumption was 4637.3 kWH.

Load Center 6 (LC-6) feeds UPS power throughout the fourth floor and to Panel C-7 (PNL C-7) on the second floor. By measuring the energy used by LC-6 and deducting the energy used by PNL C-7 we can determine the UPS power used on the fourth floor. For an average twenty-four hour period this power consumption is 5344.7 kWH. Since this is power serving the whole fourth floor we assume that the power utilization is uniform across the floor and the data center under study comprises 15.7% of the fourth floor, therefore LC-6 supplied 837.6 kWH of energy to the control volume.

To get the total power consumed by the fourth floor the sum of the data for the adjusted Load Center 6, PDP 4-4, and CDP 4-1 was calculated. An equivalent amount of cooling must be supplied to the control volume to remove the heat. Table 6 summarizes these calculations:

4th Floor Data Center Energy Consumption		
Total for 24 hour period	5614.8	kWH
Energy Consumed	19157712	BTU
Energy Flow Rate	798238	BTU/Hr
Energy Flow Rate	66.52	Tons of Refrigeration

Table 6 Control Volume total energy

In order to confirm the amount of chilled water being used to cool the fourth floor, we attempted to measure the flow and temperature differential of the chiller water feeding the fourth floor. When we arrived on site to install the fluid thermal energy meter, the intended site for installation was determined to be unsuitable for the connection of the meter. We chose an alternate location, however this secondary location did not capture all the flow to the fourth floor. The data collected by the meter is provided in Appendix A. A summary of this data is provided in table 7.

Total Flow	209,260 gal.
Avg Flow Rate	169.52 gpm
Avg dT	0.077°F
Period of Measure	41:15:00
Total Energy Flow	118,560 BTU
Avg 24 Hr Period Flow	170.68 gpm
Avg 24 Hr Energy Flow	70,694 BTU
Power Density	29.01 w/sf

Table 7 Control Volume Chilled Water Measurements

In order to determine if there is a significant relationship between weather patterns and data center power usage we gathered cooling degree days and heating degree day data for the time period under study and charted it against the power consumption for the site for the same time period. The data was taken from US Department of Commerce NOAA Historical Climatology data and the results are displayed below.

	Cooling Degree Days (65 deg F)	Heating Degree Days (65 deg F)	MWH
1997	569	5941	57463.2
1998	754	4948	42155.6
1999	875	5404	32174.7
2000	502	5910	32005.0
2001	713	5349	29861.2
2002	133	3224	31924.3

Table 8 Climatology data

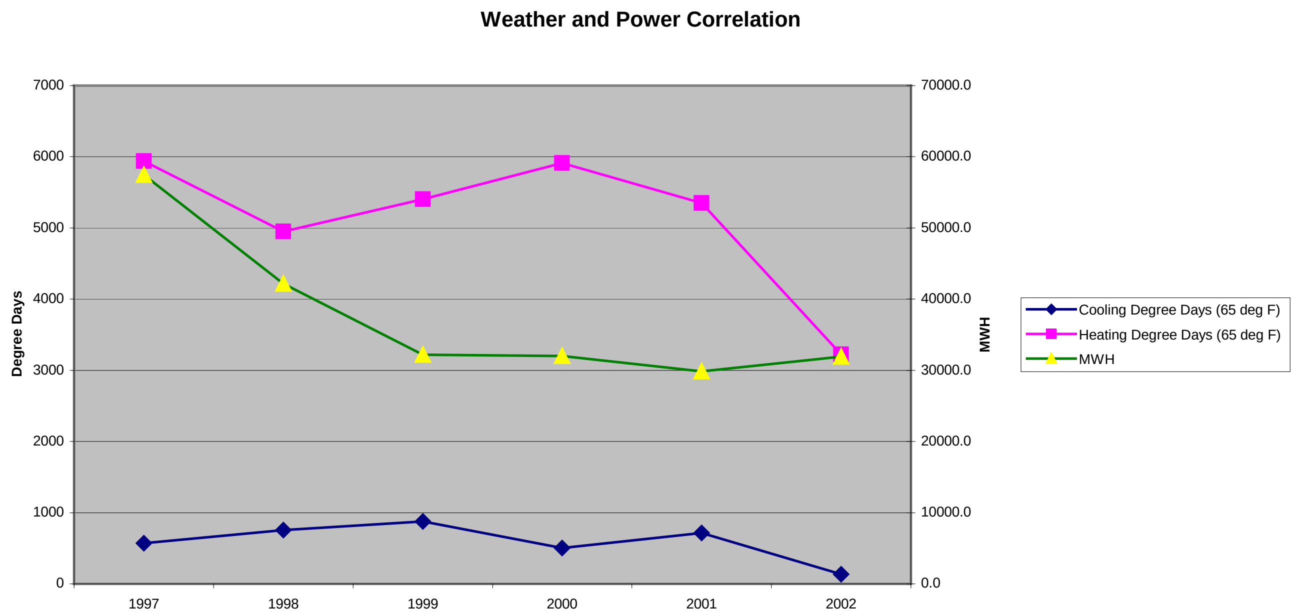


Figure 11 Weather and Power Correlation

As the graph illustrates, there is no distinct correlation between the weather and the power usage by the site. This reinforces the 24 by 7 nature of data center operations and that the computing loads dominate regardless of the outdoor conditions.

Conclusions

CONTROL VOLUME B

The thermal energy measurements indicate that the CRAC systems being measured were not providing cooling. This may be the result of the areas on the fourth floor being idle or it could be due to the control of the two HVAC systems. Additionally our measurements did not capture the chilled water flow to the two air handlers in the penthouse above the fourth floor, these units apparently are handling the majority of the cooling for the fourth floor. It appears that the computer room air conditioning units are simply recirculating the air without providing cooling.

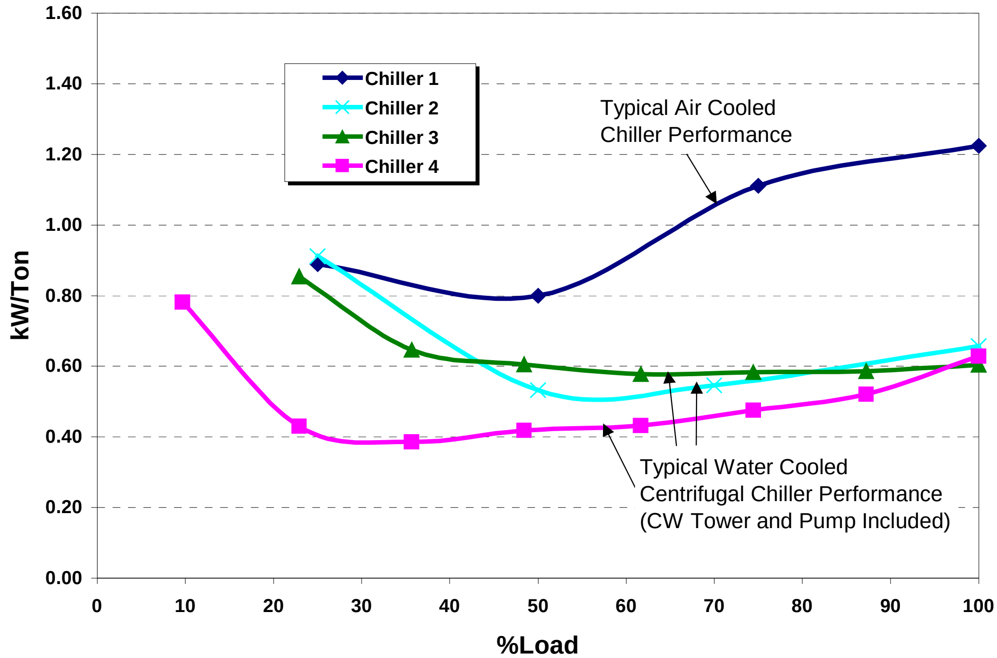
ENERGY EFFICIENCY OPPORTUNITIES:

GENERAL GUIDELINES FOR FUTURE CONSTRUCTION

Efficient Chilled Water Systems

Water cooled chillers offer enormous energy savings over air cooled chillers. Since the chiller is being cooled by lower temperature media, it can reject heat more easily, and does not have to work as hard. Though the addition of a cooling tower adds maintenance costs associated with the water treatment, we have found that the energy savings outweigh the maintenance costs. Within the options of water cooled chillers, variable speed centrifugal are the most energy efficient, because they can operate very efficiently at low loads. The graph below compares the energy performance of various chiller types.

Comparison of Typical Chiller Efficiencies over Load Range



Chiller 1	250-Ton, Screw, Standard Efficiency, Air Cooled
Chiller 2	216 Ton, Screw, Water Cooled
Chiller 3	227-Ton, Centrifugal, Constant Speed, Water Cooled
Chiller 4	227-Ton, Centrifugal, Variable Speed, Water Cooled

Figure 12 Chiller Comparisons

Though there are efficient air cooled chillers, the larger size of water cooled chillers has resulted in more care given to efficiency and life cycle costs compared to air cooled chillers.

The selection of the auxiliary equipment, including the cooling tower, pumps, and pumping strategy should also be considered carefully. For example, variable speed fans on cooling towers allow for optimized cooling tower control. Premium efficiency motors and high efficiency pumps are recommended, and variable speed pumping is a ripe opportunity for pump savings. Variable pumping strategies can be achieved in a primary/secondary scheme, where the primary pumps operate at constant speed and directly feed water to the chiller, and the secondary pumps are variable speed and serve the air handling units. A more energy efficient scheme is primary-only variable speed pumping strategy. Pumping savings are based on the cube law: pump power is reduced by the cube of the reduction in pump speed, which is directly proportional to the amount of fluid pumped.

A primary only variable pumping strategy must include a bypass valve that ensures minimum flow to the chiller, and the use of two-way valves at the air handling units in order to achieve lower pumping speeds. The control speed of the bypass valve should also meet the chiller manufacturers recommendations of allowable turndown, such that optimum chiller efficiency is achieved. This basically means that the flow through the chiller should be varied slow enough such that the chiller is able to reach a quasi-steady state condition and able to perform to its maximum efficiency. The diagram below describes the primary-only variable speed pumping strategy.

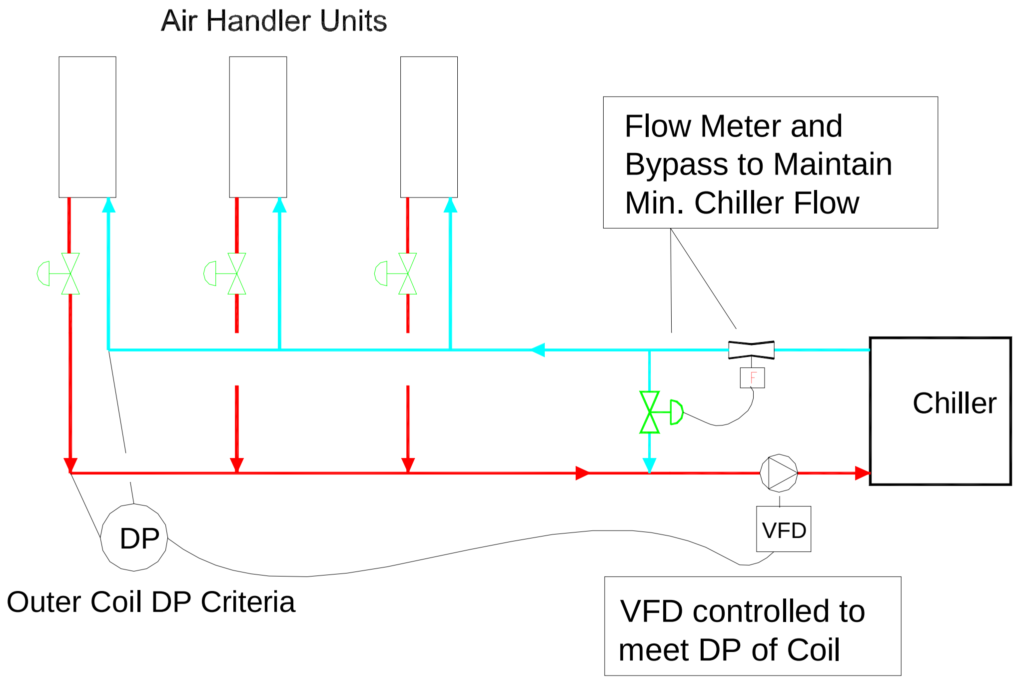


Figure 13 Air Handler Units

Air Management

A traditional method of cooling data centers employs an underfloor system fed by CRAC units. There are a number of potential problems with such systems: an underfloor system works on the basis of thermal stratification. This means that as the cool air is fed from the underfloor, it absorbs energy from the space, warming up as a result, and rises. In order to take advantage of thermal stratification, the return air must be collected at the ceiling level. CRAC units often have low return air grills, and are therefore simply recirculating cool or moderately warmed air. Furthermore, they are often located along the perimeter of the building, and not dispersed throughout the floor area where they can more effectively treat warm air. One alternative is to install transfer grills from the ceiling to the return grill.

Another common problem with underfloor supply is that the underfloor becomes congested with cabling, increasing the resistance to air flow. This results in an increase in fan energy use. A generous underfloor depth is essential for effective air distribution. Congested underfloor areas were observed in the control volume space as the following figure illustrates:

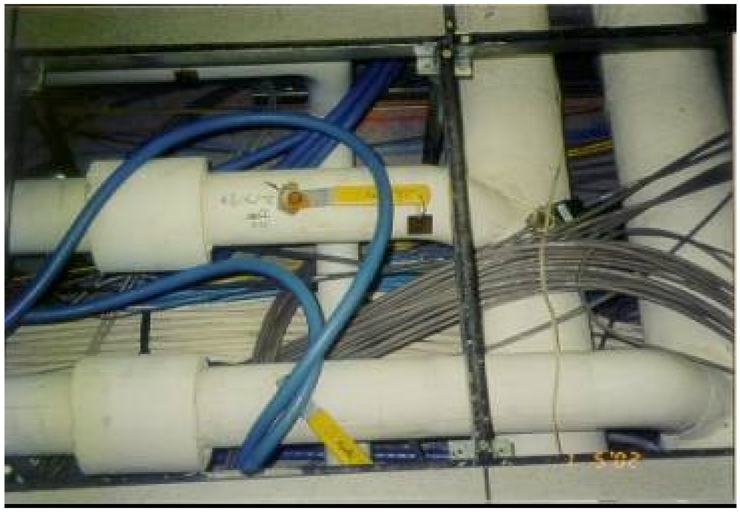


Figure 14 This under floor area in the NY Data Center severely restricts air flow

An alternative to underfloor air distribution is high velocity overhead supply, combined with ceiling height return. A central air handling system can be a very efficient air distribution unit. Design considerations include using VFDs on the fans, low pressure drop filters, and coils. An additional advantage of a central air handling system is that it can be specified with an economizer function.

Another common problem identified with CRAC units is that they are often fighting each other in order to maintain a constant humidity setpoint. Not only is a constant humidity setpoint unnecessary for preventing static electricity (the lower limit is more important), but it uses extra energy. A central air handling unit has better ability to control overall humidity than distributed CRAC units.

Air Management – Rack Configuration

Server rack configuration also dictates air management strategies in data centers. It is more logical for the aisles to be arranged such that servers' backs are facing each other, and servers' fronts are facing each other. This way, cool air is drawn in through the front, and hot air blown out the back (assuming a front to back server). The Uptime Institute has published documents describing this method for air management.

Commissioning of New Systems and Optimized Control Strategies

Many times the predicted energy savings of new and retrofit projects are not fully realized. Often, this is due to poor and/or incomplete implementation of the energy efficiency recommendations. Commissioning is the process of ensuring that the building systems perform as they were intended to by the design. Effective commissioning actually begins at the design stage, such that the design strategy is critically reviewed. Either the design engineer can serve as the commissioning agent, or a third party commissioning agent can be hired. Commissioning differentiates from standard start-up testing in that it ensures systems function well relative to each other. In other words, it employs a systems approach.

Many of the problems identified in building systems are often associated with controls. A good controls scheme begins early in the design. In our experience, an effective controls design includes 1) a detailed points list, with accuracy levels, and sensor types, and 2) a detailed sequence of operations. Both of these components are essential for successfully implementing the recommended high efficiency chilled water system described above.

It is also possible that computer room air conditioners can be simultaneously cooling and humidifying – or heating and cooling at the same time. As noted below, however, it appears that cooling is not being provided by the CRAC units for the data center area examined.

Though use of commissioning is not uniformly adopted, various organizations have developed standards and guidelines. Such guidelines are available through organizations like Portland Energy Conservation Inc., at www.peci.org, or ASHRAE, Guideline 1-1996.

SPECIFIC OBSERVATIONS

Computer Room Air Conditioning

Based upon the measured data, it appears that very little, if any, cooling is provided by the computer room air conditioners. The inlet and exit temperatures of the chilled water to the CRAC units were approximately the same. It appears that the central building HVAC units are handling the entire cooling load for the computers and the CRAC units fan heat. If this is the case, there may also be greater outside air ventilation occurring than is necessary. Use of this system for total cooling may be the most efficient arrangement but deserves further study. The CRAC units are merely mixing the air in the data center areas. While this may be useful to avoid local hot spots, they apparently are not needed to provide overall cooling. It may be possible turn off some or all of the CRAC units and still achieve adequate cooling. This would save fan energy (and its added heat) for the units shut down. Further, with some modification to the distribution of the central system, it may be possible to eliminate the need for the CRAC units. Shutting off the units could save up to 330,400 kWh/year or $25,000-$30,000 per year.

The site should confirm that the central HVAC system is carrying the cooling load (by further monitoring of the chilled water inlet and outlet temperatures). If this is confirmed, the chilled water to the CRAC units could be then be turned off saving pumping energy. Approximately 169 gpm is provided to the CRAC units on a continuous basis. Given that the chilled water is being pumped to the fourth floor through a long, complicated piping system, there is considerable opportunity for savings if the flow can be reduced or eliminated.

Openings were observed around many pieces of computing equipment through the raised floor. Sealing floor openings can improve efficiency by directing air through floor tiles to where it is needed. An air management scheme as described above should be followed by strategically placing floor tiles with openings in front of racks of computers.

Data center temperature and humidity control may be an opportunity for improvement. The observed temperature was colder than needed for human comfort and most likely lower than the electronics require. Studies have shown that the electrical components in data centers can withstand significantly higher temperatures and a broader range of humidity control, however the host site's customers would likely provide input to any change in operating criteria. It appears that the current computing loads are being accommodated through "brut force" cooling provided by the central air handlers. Temperatures throughout the data center could be monitored to confirm that local heat intensive areas are acceptable (if any exist).

Chilled Water System

Verify that the most efficient chiller is usually operating. Consider overall pumping energy for various combinations of chillers. Investigate use of free cooling and efficient operation of cooling towers. Various resources are available to provide guidance for chilled water systems, such as Cooltools:

(http://www.hvacexchange.com/cooltools/coolhome.htm)

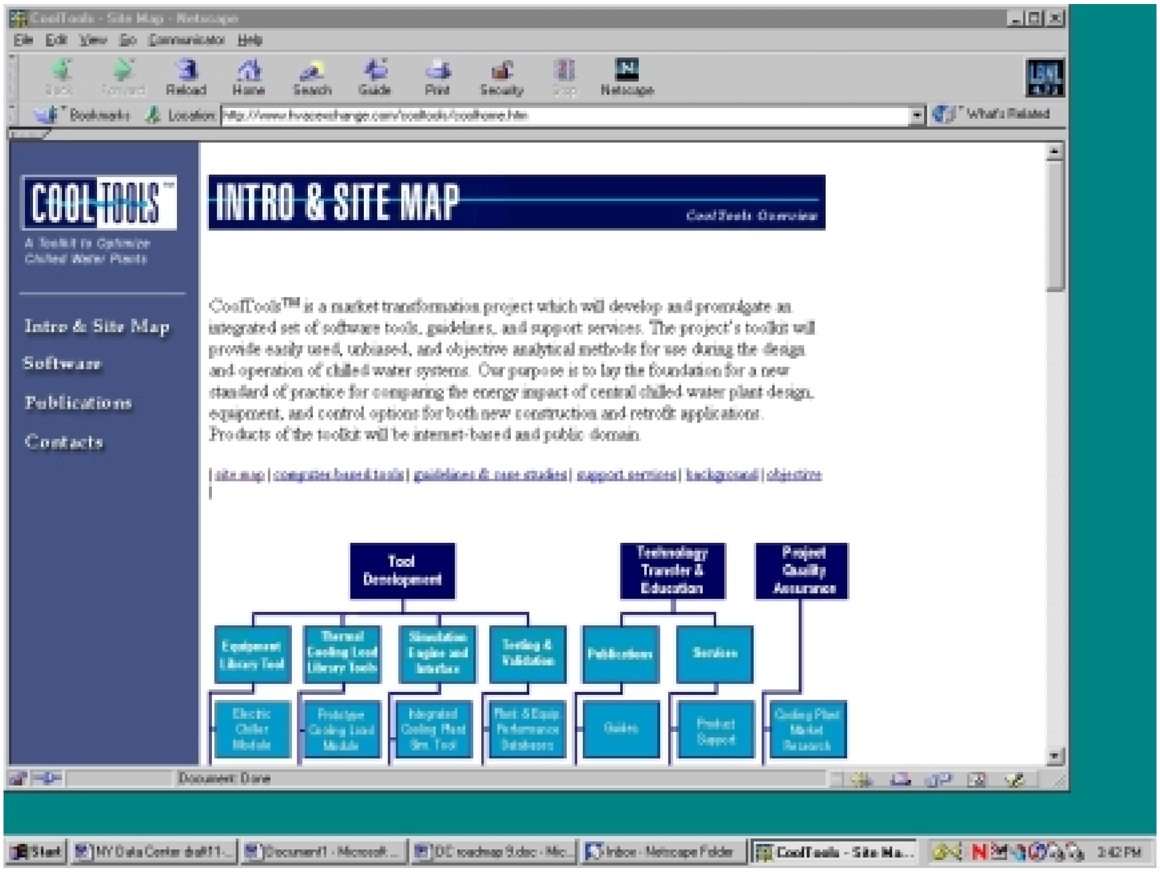


Figure 15 Cool Tools Web site

Computer room lighting

Consider use of standard lighting controls such as timers or occupancy sensors in data center areas. Many areas are unoccupied for long periods of time and comparable savings to office areas can be obtained. Consider reduced lighting levels and/or eliminating lighting in certain areas, especially in times of peak demand charges. Many telecom facilities hosting multiple customers are utilizing lighting controls to only illuminate a customer area when needed. This enhances energy savings and security. Savings for the direct cost of the lighting as well as the cost of removing the heat produced by the lighting will be realized.

Computing Equipment

Investigate ability to power down unused data processing equipment.

Appendices

Appendix A: Fluid Thermal Energy Meter Data (15 minute interval)

Appendix B: Power Monitoring Report

Appendix C: Data Center references

Appendix D: Monitoring Equipment

Appendix A: Fluid Thermal Energy Meter Data (15 minute interval)

Controlotron Data
15-minute intervals
Total: 41 hrs 15m

Date	Time	Heat Flow Rate MBTU/HR	Thermal Total MBTU	Flow Rate KGAL/MIN	Total Flow KGAL	Delta T dt(uS)
08.21.2002	15:45	0.21	0.09	0.17808	4.1	0.06821
08.21.2002	16:00	0.02	0.11	0.15772	6.45	0.07751
08.21.2002	16:15	-0.03	0.1	0.15904	8.86	0.07979
08.21.2002	16:30	-0.04	0.09	0.16341	11.31	0.0746
08.21.2002	16:45	-0.09	0.08	0.16533	13.76	0.07365
08.21.2002	17:00	-0.05	0.06	0.16393	16.19	0.0733
08.21.2002	17:15	-0.04	0.05	0.15955	18.62	0.0721
08.21.2002	17:30	-0.05	0.04	0.16692	21.08	0.07218
08.21.2002	17:45	-0.05	0.03	0.16048	23.49	0.08074
08.21.2002	18:00	-0.05	0.01	0.15777	25.88	0.07492
08.21.2002	19:30	-0.09	-0.08	0.16073	40.17	0.06786
08.21.2002	19:45	-0.08	-0.1	0.15737	42.55	0.07029
08.21.2002	20:00	-0.08	-0.12	0.15712	44.92	0.07952
08.21.2002	20:15	-0.08	-0.15	0.14388	47.2	0.06598
08.21.2002	20:30	-0.11	-0.17	0.15669	49.48	0.07263
08.21.2002	20:45	-0.09	-0.2	0.16235	51.89	0.07397
08.21.2002	21:00	-0.09	-0.22	0.16064	54.29	0.06896
08.21.2002	21:15	-0.1	-0.24	0.15805	56.67	0.0682
08.21.2002	21:30	-0.09	-0.26	0.15684	59.01	0.0677
08.21.2002	22:00	-0.09	-0.31	0.15903	63.68	0.07166
08.21.2002	22:15	-0.09	-0.33	0.1521	65.97	0.06885
08.21.2002	22:30	-0.1	-0.36	0.15255	68.25	0.06936
08.21.2002	22:45	-0.1	-0.38	0.14898	70.51	0.06286
08.21.2002	23:00	-0.11	-0.41	0.15238	72.75	0.0611
08.21.2002	23:15	-0.1	-0.44	0.14712	74.98	0.06834
08.21.2002	23:30	-0.1	-0.46	0.14592	77.21	0.06936
08.21.2002	23:45	-0.1	-0.49	0.14316	79.39	0.06633
08.22.2002	0:00	-0.11	-0.51	0.14438	81.55	0.07021
08.22.2002	0:15	-0.1	-0.54	0.14325	83.72	0.06607
08.22.2002	0:30	-0.1	-0.57	0.1411	85.85	0.06733
08.22.2002	0:45	-0.1	-0.59	0.14209	88.01	0.0572
08.22.2002	2:15	-0.11	-0.75	0.13863	100.66	0.066
08.22.2002	2:30	-0.06	-0.77	0.14309	102.75	0.07048
08.22.2002	2:45	-0.04	-0.78	0.1492	104.98	0.06838
08.22.2002	3:00	-0.04	-0.79	0.156	107.27	0.0712
08.22.2002	3:15	-0.03	-0.8	0.15522	109.6	0.07353

Date	Time	Heat Flow Rate MBTU/HR	Thermal Total MBTU	Flow Rate KGAL/MIN	Total Flow KGAL	Delta T dt(uS)
08.22.2002	3:30	-0.04	-0.8	0.15728	111.94	0.07286
08.22.2002	3:45	-0.04	-0.81	0.16208	114.33	0.07215
08.22.2002	4:00	-0.03	-0.82	0.16066	116.71	0.07533
08.22.2002	4:15	-0.03	-0.83	0.16193	119.12	0.07186
08.22.2002	4:30	-0.03	-0.83	0.16315	121.56	0.07406
08.22.2002	4:45	-0.02	-0.84	0.16504	124.03	0.07473
08.22.2002	5:00	-0.03	-0.85	0.16418	126.52	0.08268
08.22.2002	5:15	-0.03	-0.85	0.16583	129	0.07706
08.22.2002	5:30	-0.03	-0.86	0.16808	131.51	0.07232
08.22.2002	5:45	-0.03	-0.87	0.16693	134.01	0.08324
08.22.2002	6:00	-0.03	-0.87	0.1687	136.51	0.07396
08.22.2002	6:15	-0.03	-0.88	0.16568	139	0.07892
08.22.2002	6:30	-0.03	-0.89	0.16736	141.49	0.07264
08.22.2002	6:45	-0.03	-0.89	0.16788	144	0.07477
08.22.2002	7:00	-0.03	-0.9	0.16731	146.5	0.06875
08.22.2002	7:15	-0.03	-0.91	0.16613	149	0.07821
08.22.2002	7:30	-0.02	-0.91	0.16753	151.5	0.07436
08.22.2002	7:45	-0.01	-0.92	0.16752	154.05	0.07938
08.22.2002	8:00	-0.06	-0.93	0.16012	156.53	0.07161
08.22.2002	8:15	-0.09	-0.95	0.15151	158.83	0.06791
08.22.2002	8:30	-0.09	-0.97	0.15336	161.14	0.07168
08.22.2002	8:45	-0.09	-0.99	0.15439	163.46	0.0759
08.22.2002	9:00	-0.09	-1.02	0.15714	165.83	0.073
08.22.2002	9:15	-0.1	-1.04	0.1591	168.15	0.07045
08.22.2002	9:30	-0.09	-1.06	0.15812	170.54	0.07352
08.22.2002	9:45	-0.09	-1.08	0.16275	172.95	0.07239
08.22.2002	10:00	-0.09	-1.11	0.16564	175.39	0.07348
08.22.2002	10:15	-0.08	-1.13	0.1631	177.82	0.07523
08.22.2002	10:30	-0.1	-1.15	0.16385	180.24	0.06957
08.22.2002	10:45	-0.09	-1.18	0.16101	182.67	0.0762
08.22.2002	11:00	-0.09	-1.2	0.16635	185.16	0.07428
08.22.2002	11:15	-0.1	-1.22	0.16644	187.65	0.07455
08.22.2002	11:30	-0.09	-1.25	0.16928	190.16	0.07491
08.22.2002	11:45	-0.09	-1.27	0.16928	192.69	0.07544
08.22.2002	12:00	-0.08	-1.29	0.16761	195.22	0.0772
08.22.2002	12:15	-0.09	-1.31	0.17112	197.78	0.07605
08.22.2002	12:30	-0.06	-1.33	0.16929	200.32	0.07966
08.22.2002	12:45	-0.01	-1.34	0.17745	202.96	0.08341
08.22.2002	13:00	-0.01	-1.34	0.18218	205.69	0.08095
08.22.2002	13:15	0.01	-1.34	0.18514	208.44	0.08448
08.22.2002	13:30	0.02	-1.33	0.18496	211.19	0.08086
08.22.2002	13:45	0	-1.33	0.18296	213.95	0.08454
08.22.2002	14:00	0.01	-1.33	0.184	216.7	0.08084
08.22.2002	14:15	0.01	-1.33	0.18703	219.49	0.08865
08.22.2002	14:30	0.01	-1.33	0.18592	222.29	0.08231

Date	Time	Heat Flow Rate MBTU/HR	Thermal Total MBTU	Flow Rate KGAL/MIN	Total Flow KGAL	Delta T dt(uS)
08.22.2002	14:45	0.02	-1.32	0.18566	225.08	0.0825
08.22.2002	15:00	0.01	-1.32	0.1845	227.84	0.08217
08.22.2002	15:15	0.02	-1.32	0.18907	230.65	0.08599
08.22.2002	15:30	0.02	-1.31	0.18614	233.45	0.08499
08.22.2002	15:45	0.01	-1.31	0.18785	236.25	0.08622
08.22.2002	16:00	0.04	-1.3	0.18929	239.07	0.08356
08.22.2002	16:15	0.04	-1.29	0.18777	241.91	0.08598
08.22.2002	16:30	0.03	-1.29	0.1868	244.75	0.08544
08.22.2002	16:45	0.03	-1.28	0.18437	247.52	0.08986
08.22.2002	17:00	0.05	-1.26	0.18762	250.33	0.08397
08.22.2002	17:15	0.04	-1.25	0.18514	253.09	0.0815
08.22.2002	17:30	0.05	-1.24	0.18523	255.87	0.08461
08.22.2002	17:45	0.05	-1.23	0.18467	258.64	0.08081
08.22.2002	18:00	0.05	-1.22	0.18395	261.38	0.08397
08.22.2002	18:15	0.05	-1.21	0.18015	264.11	0.08146
08.22.2002	19:45	0.05	-1.12	0.18149	280.5	0.08071
08.22.2002	20:00	0.05	-1.11	0.18042	283.21	0.08223
08.22.2002	20:15	0.04	-1.1	0.18207	285.91	0.07933
08.22.2002	20:30	0.04	-1.09	0.1811	288.63	0.0808
08.22.2002	20:45	0.04	-1.08	0.18201	291.36	0.0819
08.22.2002	21:00	0.03	-1.07	0.17948	294.08	0.08414
08.22.2002	21:15	0.03	-1.06	0.17893	296.76	0.08185
08.22.2002	21:30	0.03	-1.05	0.18042	299.47	0.08672
08.22.2002	21:35	0.04	-1.05	0.18202	300.38	0.08451
08.22.2002	21:45	0.04	-1.04	0.18001	302.16	0.08468
08.22.2002	22:00	0.04	-1.03	0.17657	304.83	0.08178
08.22.2002	22:15	0.04	-1.02	0.17571	307.48	0.0783
08.22.2002	22:30	0.05	-1.01	0.17751	310.12	0.07788
08.22.2002	22:45	0.05	-1	0.17537	312.75	0.07877
08.22.2002	23:00	0.05	-0.99	0.17504	315.38	0.07741
08.22.2002	23:15	0.05	-0.97	0.17667	318.02	0.07922
08.22.2002	23:30	0.05	-0.96	0.17476	320.65	0.08074
08.22.2002	23:45	0.05	-0.95	0.17617	323.29	0.08192
08.23.2002	0:00	0.05	-0.93	0.17722	325.95	0.07759
08.23.2002	0:15	0.05	-0.92	0.17504	328.58	0.07872
08.23.2002	0:30	0.05	-0.91	0.17456	331.2	0.08119
08.23.2002	0:45	0.06	-0.89	0.1748	333.82	0.0829
08.23.2002	1:00	0.05	-0.88	0.17616	336.47	0.07901
08.23.2002	1:15	0.05	-0.86	0.17362	339.09	0.07759
08.23.2002	1:30	0.06	-0.85	0.17431	341.72	0.08262
08.23.2002	1:45	0.07	-0.83	0.17561	344.34	0.07911
08.23.2002	2:00	0.06	-0.82	0.17367	346.96	0.0763
08.23.2002	2:15	0.06	-0.8	0.17355	349.58	0.08122
08.23.2002	2:30	0.07	-0.79	0.17353	352.2	0.08103
08.23.2002	2:45	0.07	-0.77	0.17606	354.83	0.07651

Date	Time	Heat Flow Rate MBTU/HR	Thermal Total MBTU	Flow Rate KGAL/MIN	Total Flow KGAL	Delta T dt(uS)
08.23.2002	3:00	0.06	-0.76	0.17498	357.44	0.08108
08.23.2002	3:15	0.06	-0.74	0.17595	360.08	0.08255
08.23.2002	3:30	0.06	-0.72	0.17643	362.73	0.0826
08.23.2002	3:45	0.06	-0.71	0.17616	365.37	0.07669
08.23.2002	4:00	0.07	-0.69	0.17728	368.03	0.07914
08.23.2002	4:15	0.07	-0.68	0.17754	370.67	0.08242
08.23.2002	4:30	0.06	-0.66	0.17716	373.33	0.0845
08.23.2002	4:45	0.06	-0.64	0.17725	375.99	0.07967
08.23.2002	5:00	0.07	-0.63	0.17738	378.64	0.0778
08.23.2002	5:15	0.06	-0.61	0.17785	381.3	0.07825
08.23.2002	5:30	0.06	-0.6	0.17706	383.96	0.07938
08.23.2002	5:45	0.06	-0.58	0.17801	386.62	0.07935
08.23.2002	6:00	0.06	-0.57	0.17817	389.28	0.08251
08.23.2002	6:15	0.06	-0.55	0.17685	391.96	0.0815
08.23.2002	6:30	0.06	-0.54	0.17713	394.63	0.07781
08.23.2002	6:45	0.05	-0.52	0.17697	397.3	0.07979
08.23.2002	7:00	0.05	-0.51	0.1787	399.99	0.07984
08.23.2002	7:15	0.05	-0.5	0.17855	402.66	0.07686
08.23.2002	7:30	0.06	-0.48	0.17739	405.32	0.08144
08.23.2002	7:45	0.05	-0.47	0.18019	408.01	0.07691
08.23.2002	8:00	0.05	-0.46	0.17742	410.68	0.08327

Appendix B: Power Monitoring Report

Recovery Facility

KW PER SQ FT REPORT

DATE: AUGUST 28, 2002

Prepared for:

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Executive Summary

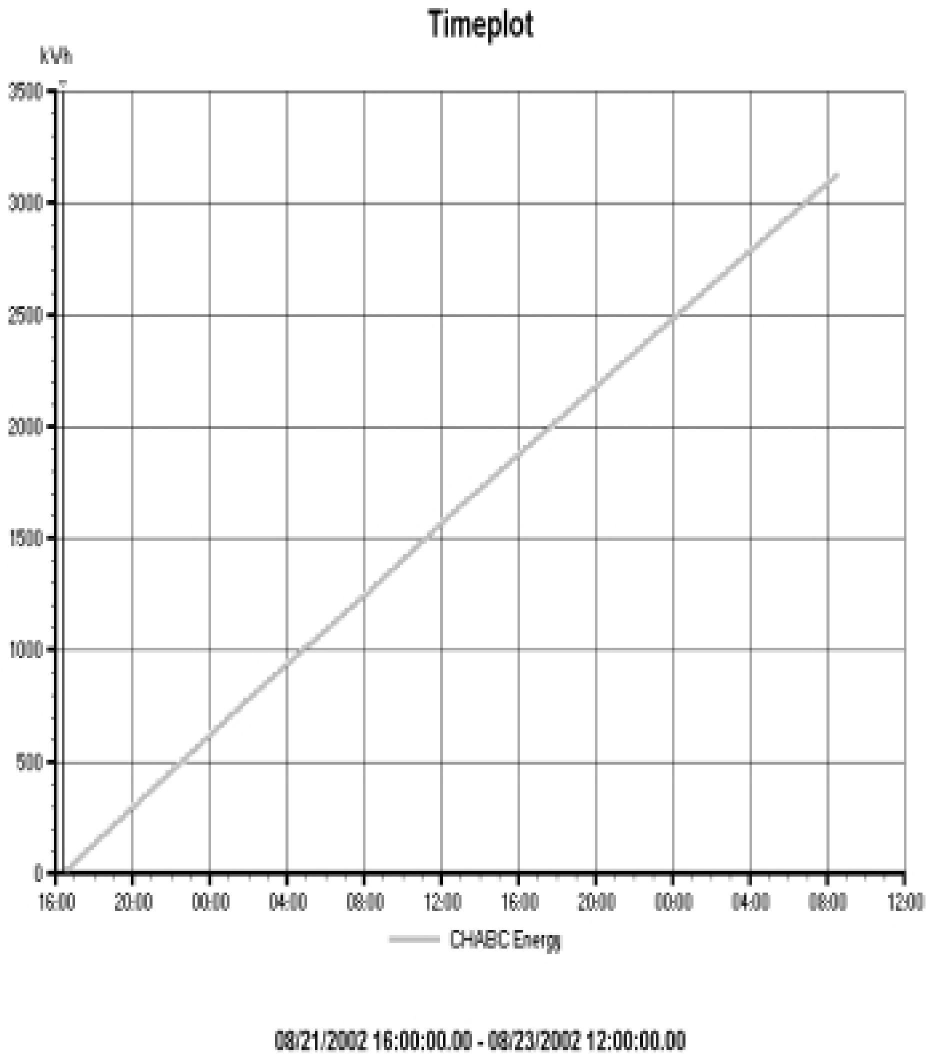
On Wednesday, August 21, 2002 three Dranetz-BMI power analyzers were installed at the host site. The monitors were installed to determine the actual kW consumption per square foot of an operating data center on a daily basis. The monitors were installed at the following locations that fed the 4th floor of the data center: PDP 4-1, CDP 4-4, and Panel CP-7. Panel CP-7 does not supply power to the 4th floor data center but instead is fed from Load Center 6. Load Center 6 contained the following feeds that supplied power to the 4th Floor data center: CDP 4-1, CDP 4-2, and CDP 4-3.

The existing GE kWh meter was utilized as the measurement source for Load Center 6. The panel CP-7 was metered so this measurement could be subtracted from the GE kWh meter resulting in the power consumption total of CDP 4-1, CDP 4-2, and CDP 4-3.

This report provides the details of the power conditions found during the day and one half of monitoring.

PDP 4-1 - kwh

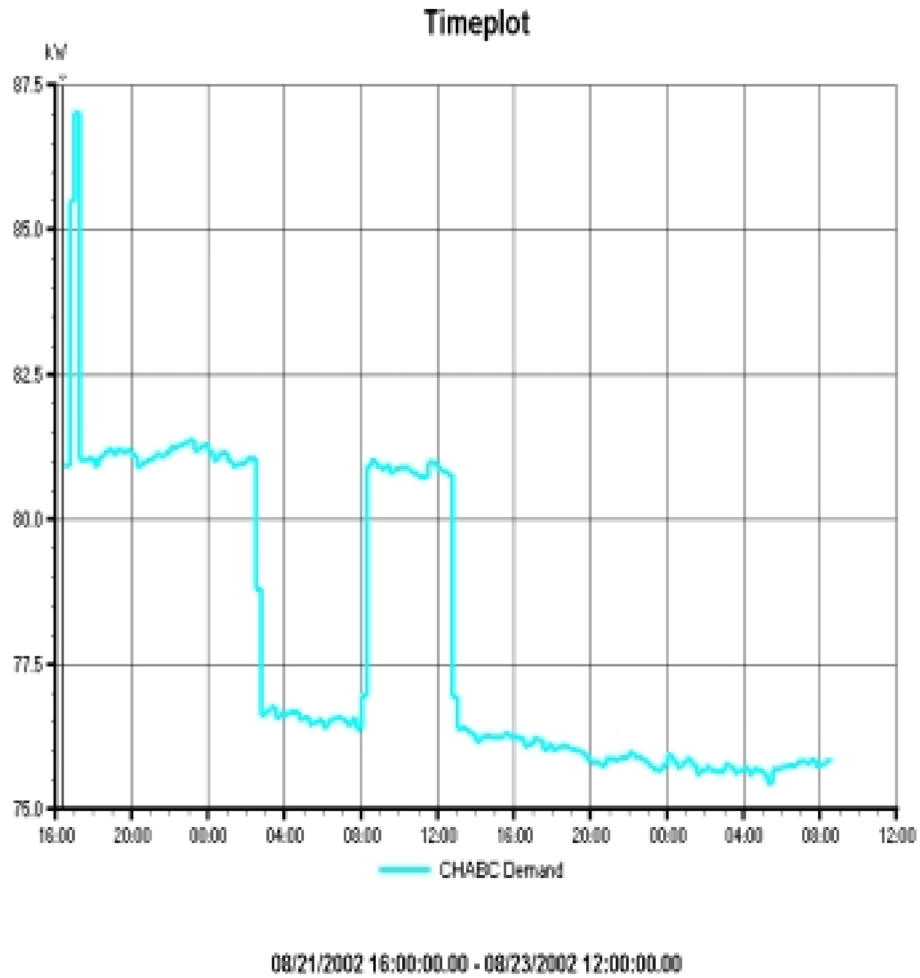
The graph below represents the minimum, maximum and median kwh consumption on PDP 4-1 over the entire monitoring period (1630 on 8/21 – 0830 on 8/23). The maximum number represents the total kwh consumed.



	Min	Max	Median
CHABC Energy	19.92	3138.4	1598.0

PDP 4-1 kw Demand

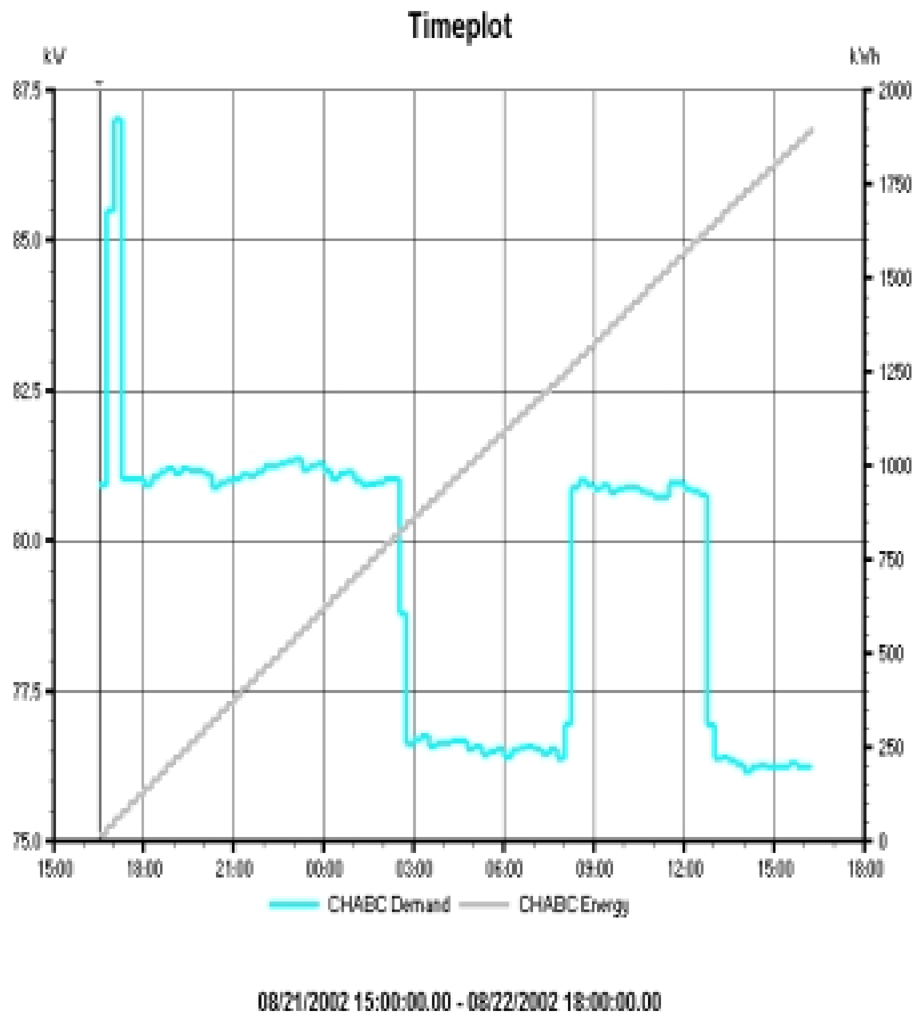
The graph below represents the minimum, maximum and median kw demand found on PDP 4-1 for the entire monitoring period (1630 on 8/21 – 0830 on 8/23).



	Min	Max	Median
CHABC Demand	75.45	87.02	76.42

PDP 4-1 Demand (kw) vs. Energy (kwh) - 24 hours

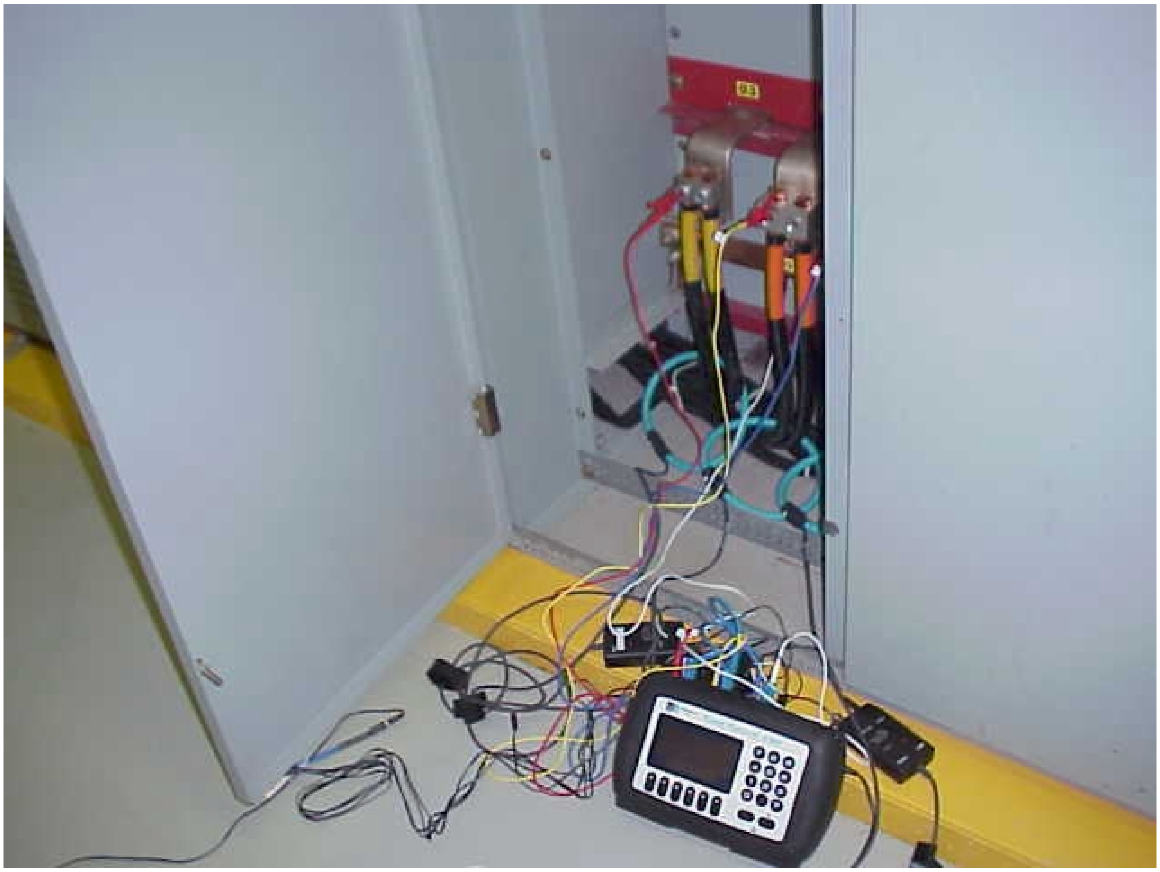
The graph below represents the minimum, maximum and median demand vs. energy conditions found PDP 4-1 on a 24-hour basis (1700 on 8/21 – 1700 on 8/22).



	Min	Max	Median
CHABC Demand	76.17	87.02	80.90
CHABC Energy	19.92	1904.3	966.78

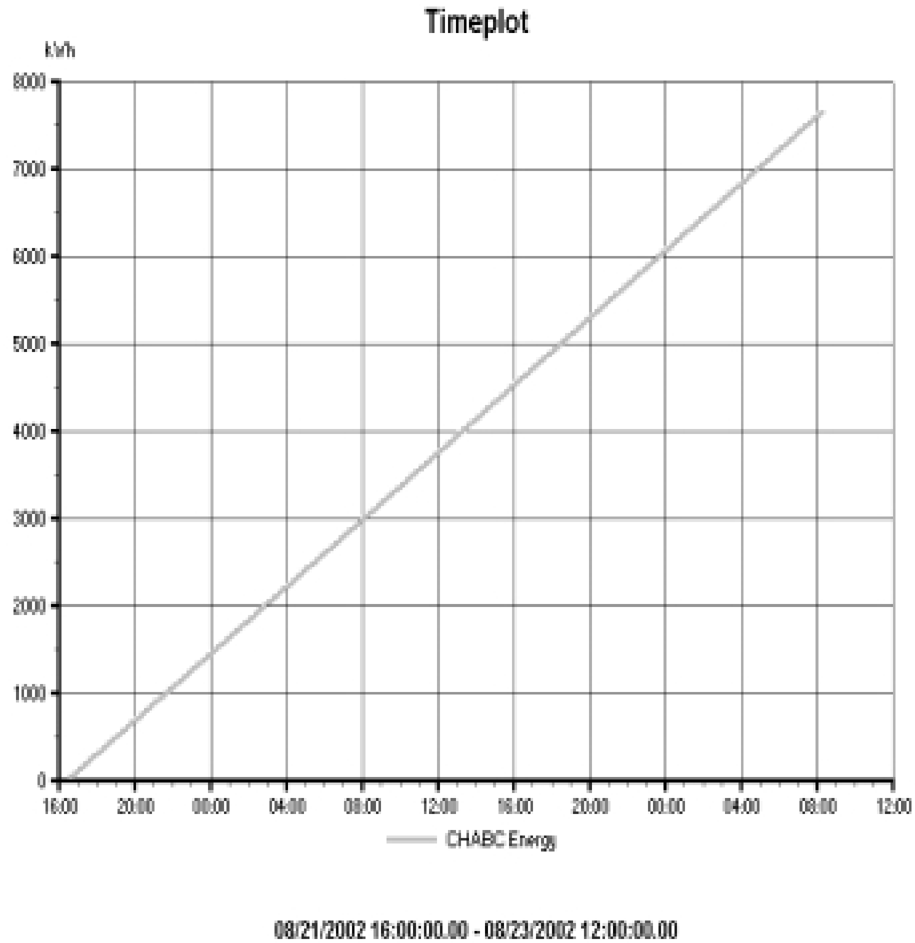
Installation Photograph – PDP 4-1

The photograph below shows the connection point of the Dranetz – BMI 4300 and associated current transformers on PDP 4-1.



CDP 4-4 kwh

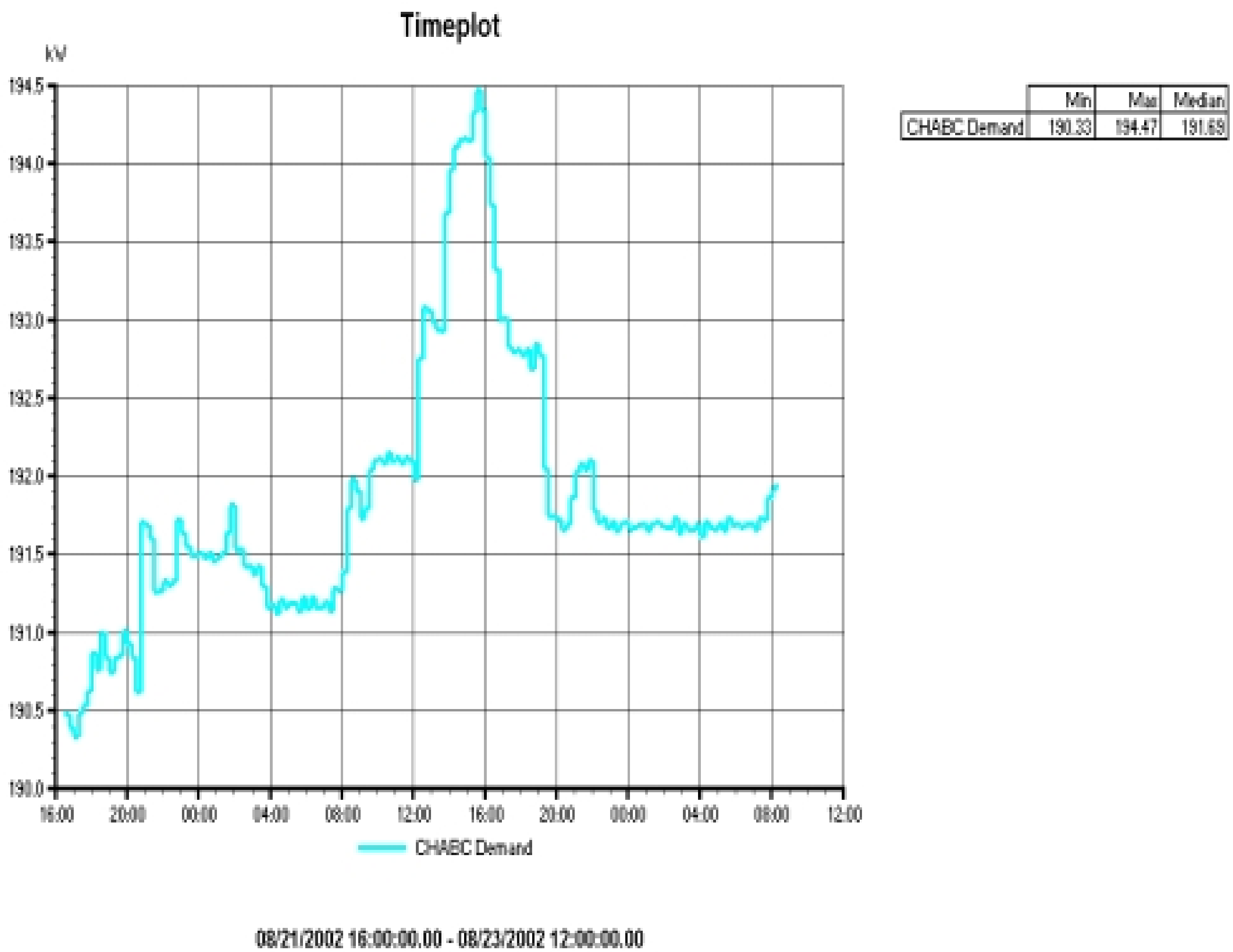
The graph below represents the minimum, maximum and median kwh consumption on PDP 4-1 over the entire monitoring period (1630 on 8/21 – 0815 on 8/23). The maximum number represents the total kwh consumed.



	Min	Max	Median
CHABC Energy	46.88	7680.5	3827.8

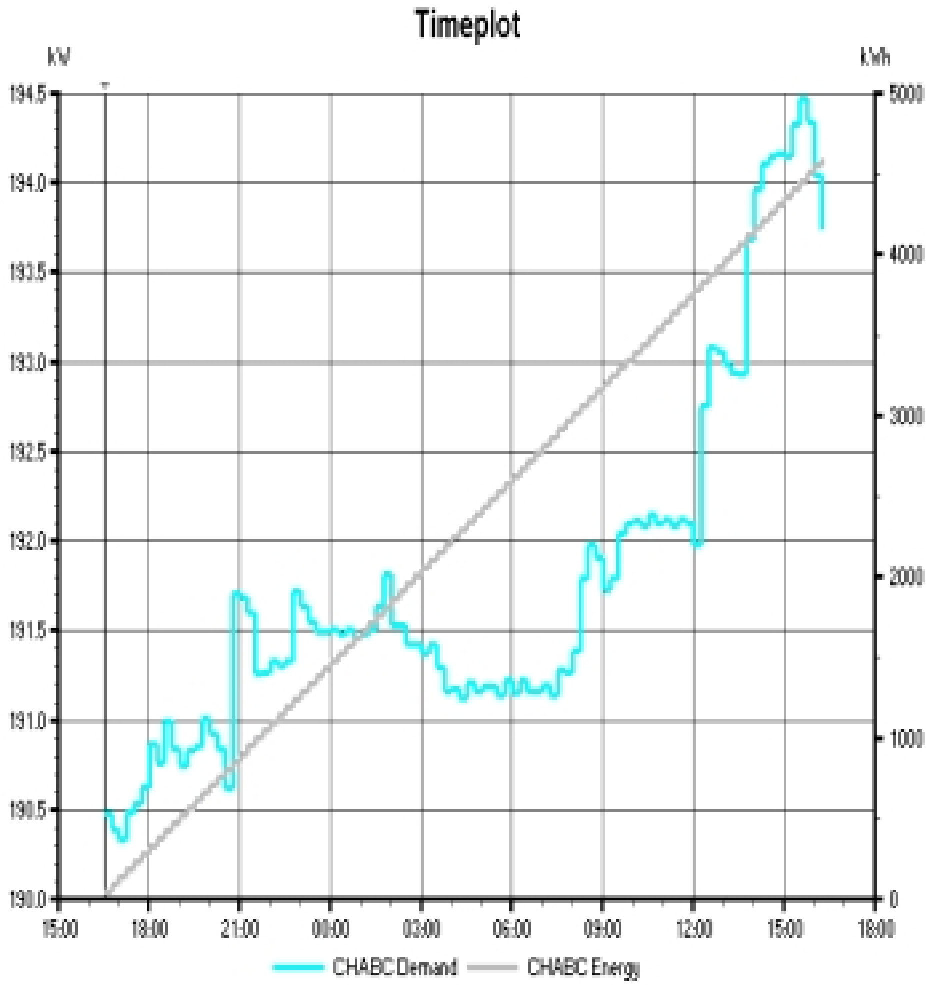
CDP 4-4 kw Demand

The graph below represents the minimum, maximum and median kw demand found on PDP 4-1 for the entire monitoring period (1630 on 8/21 – 0815 on 8/23).



CDP4-4 Demand (kw) vs. Energy (kwh) - 24 hours

The graph below represents the minimum, maximum and median demand vs. energy conditions found PDP 4-1 on a 24-hour basis (1700 on 8/21 – 1700 on 8/22).

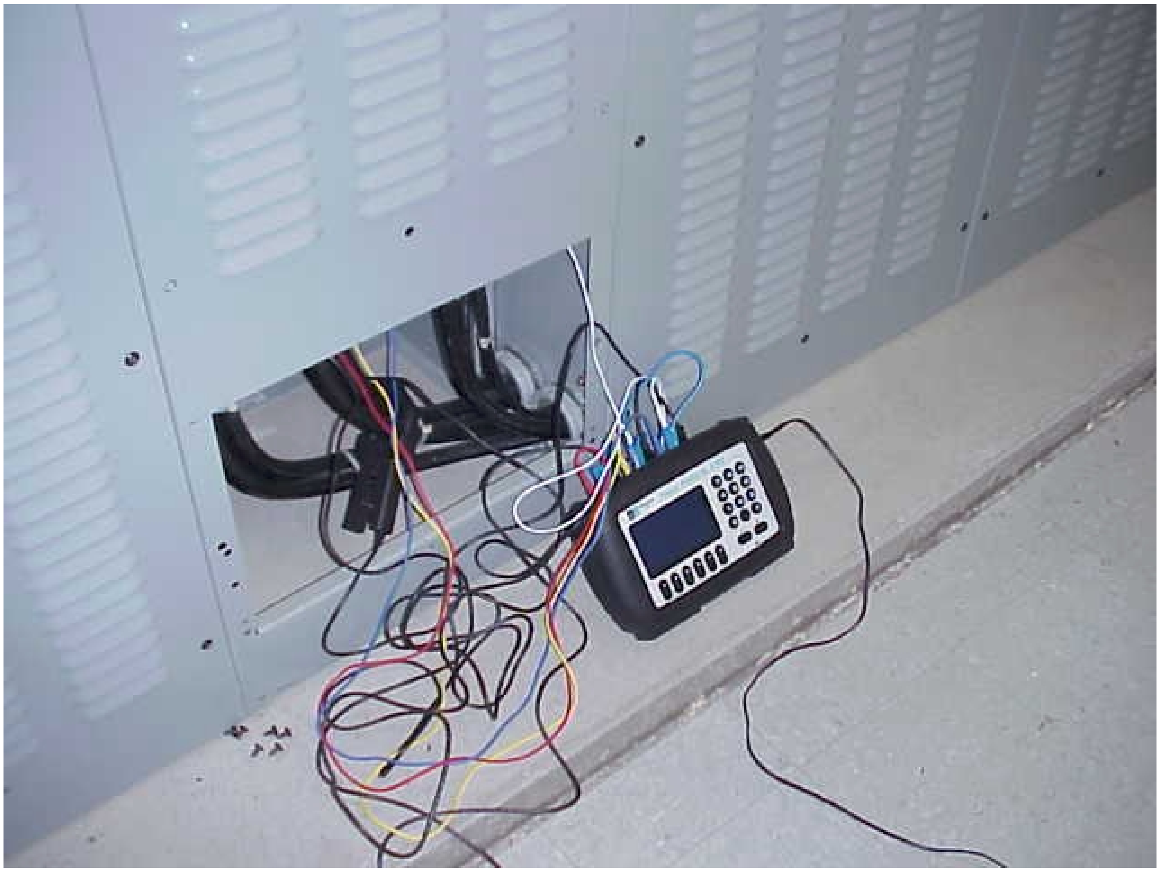


	Min	Max	Median
CHABC Demand	190.33	194.47	191.48
CHABC Energy	46.88	4603.2	2293.9

08/21/2002 15:00:00.00 - 08/22/2002 18:00:00.00

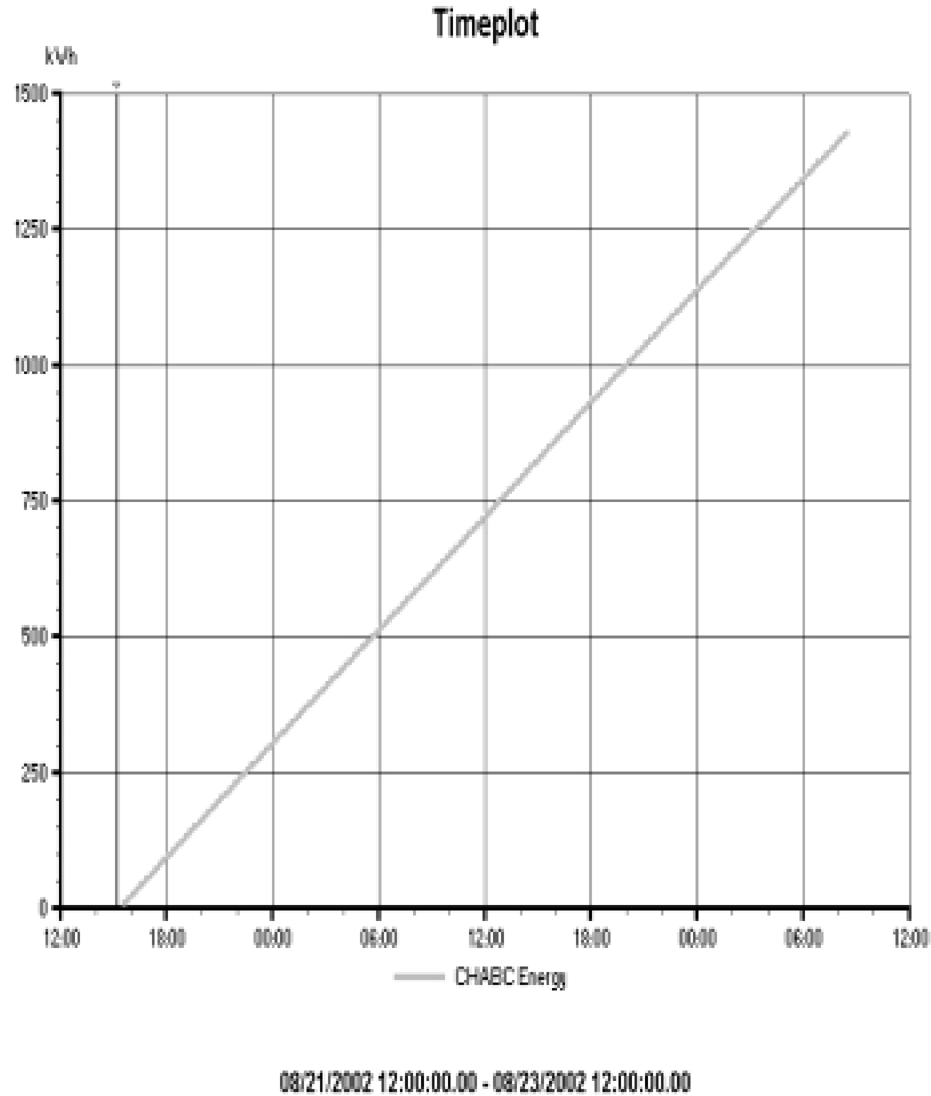
Installation Photograph – CDP 4-4

The photograph below shows the connection point of the Dranetz – BMI 4300 and associated current transformers on CDP 4-4.



Load Center 6 Panel CP-7 kwh

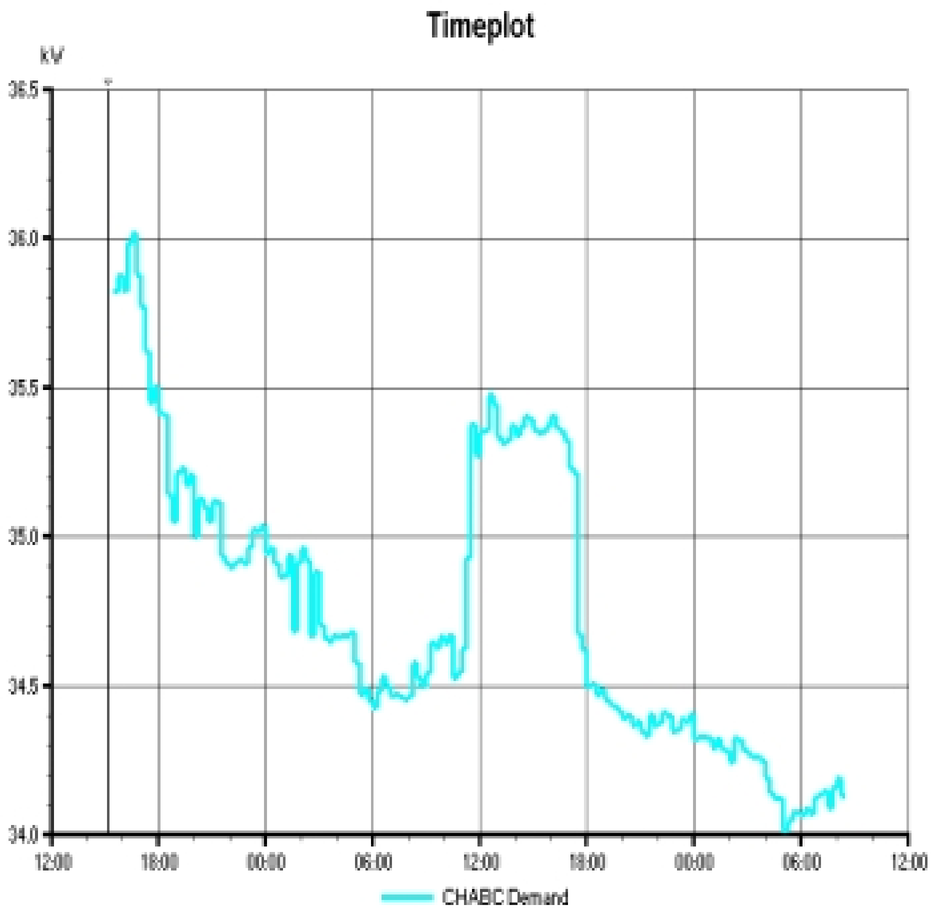
The graph below represents the minimum, maximum and median kwh consumption on CP-7 over the entire monitoring period (1530 on 8/21 – 0830 on 8/23). The maximum number represents the total kwh consumed.



	Min	Max	Median
CHABC Energy	8.84	1433.2	715.93

Load Center 6 – Panel CP-7

The graph below represents the minimum, maximum and median kw demand found on Load Center 6, Panel CP-7 for the entire monitoring period (1530 on 8/21 – 0830 on 8/23)

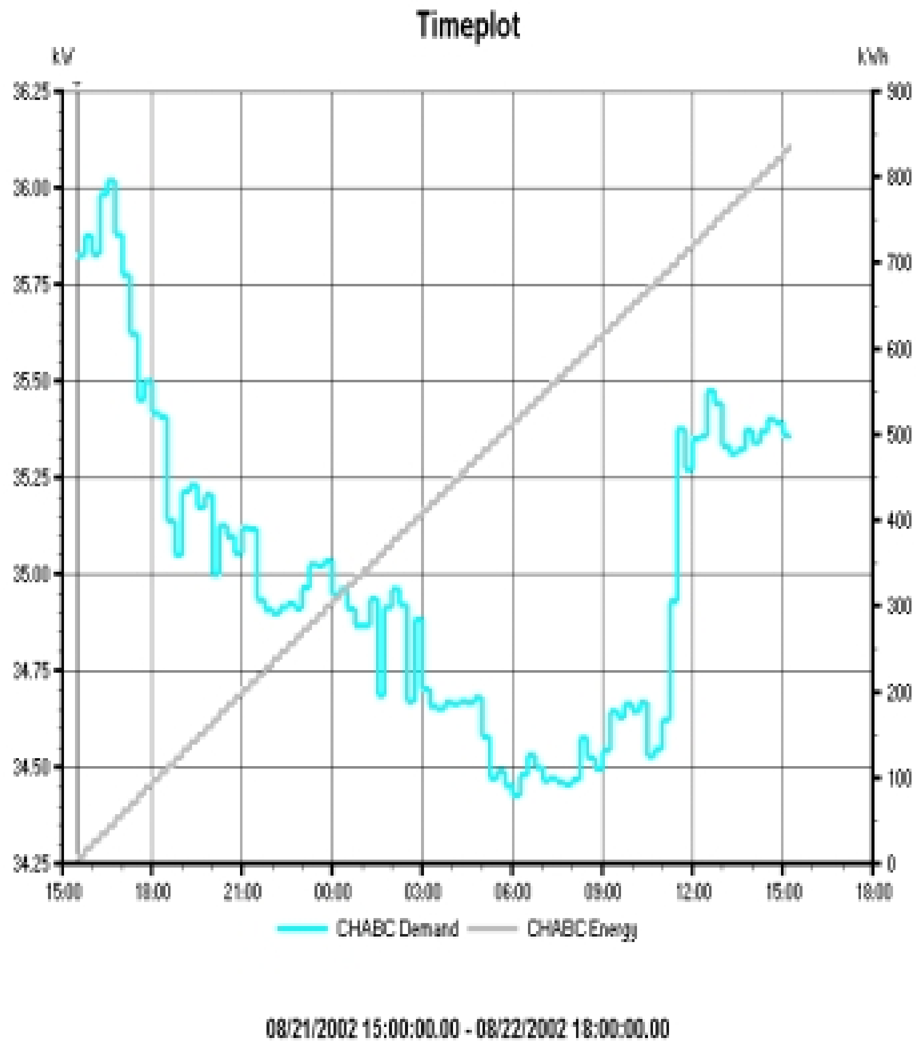


	Min	Max	Median
CHABC Demand	34.02	36.02	34.65

08/21/2002 12:00:00.00 - 08/23/2002 12:00:00.00

Load Center 6, Panel CP-7 Demand (kw) vs. Energy (kwh)

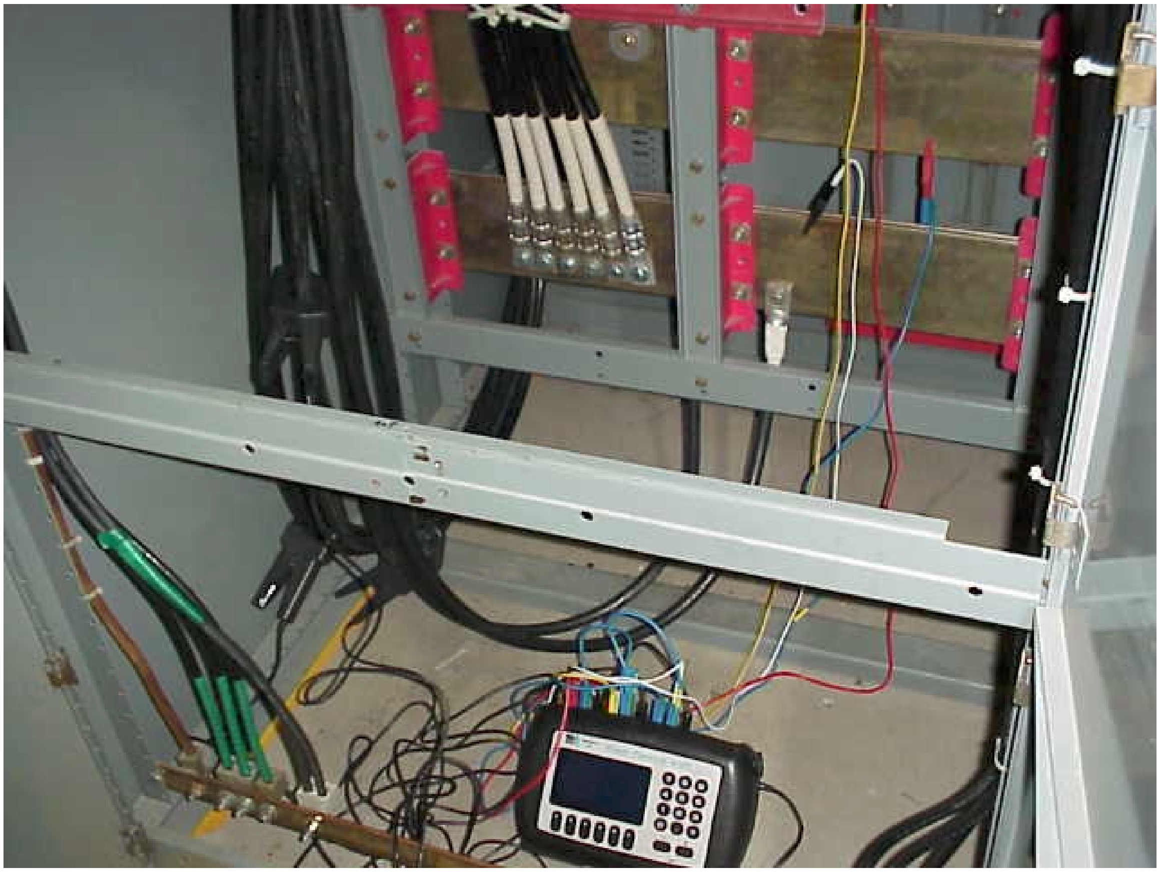
The graph below represents the minimum, maximum and median demand vs. energy conditions found CP-7 on a 24-hour basis (1700 on 8/21 – 1700 on 8/22).



	Min	Max	Median
CHABC Demand	34.43	36.02	34.93
CHABC Energy	8.84	839.80	421.74

Installation Photograph – CP-7

The photograph below shows the connection point of the Dranetz – BMI 4300 and associated current transformers on CP-7.



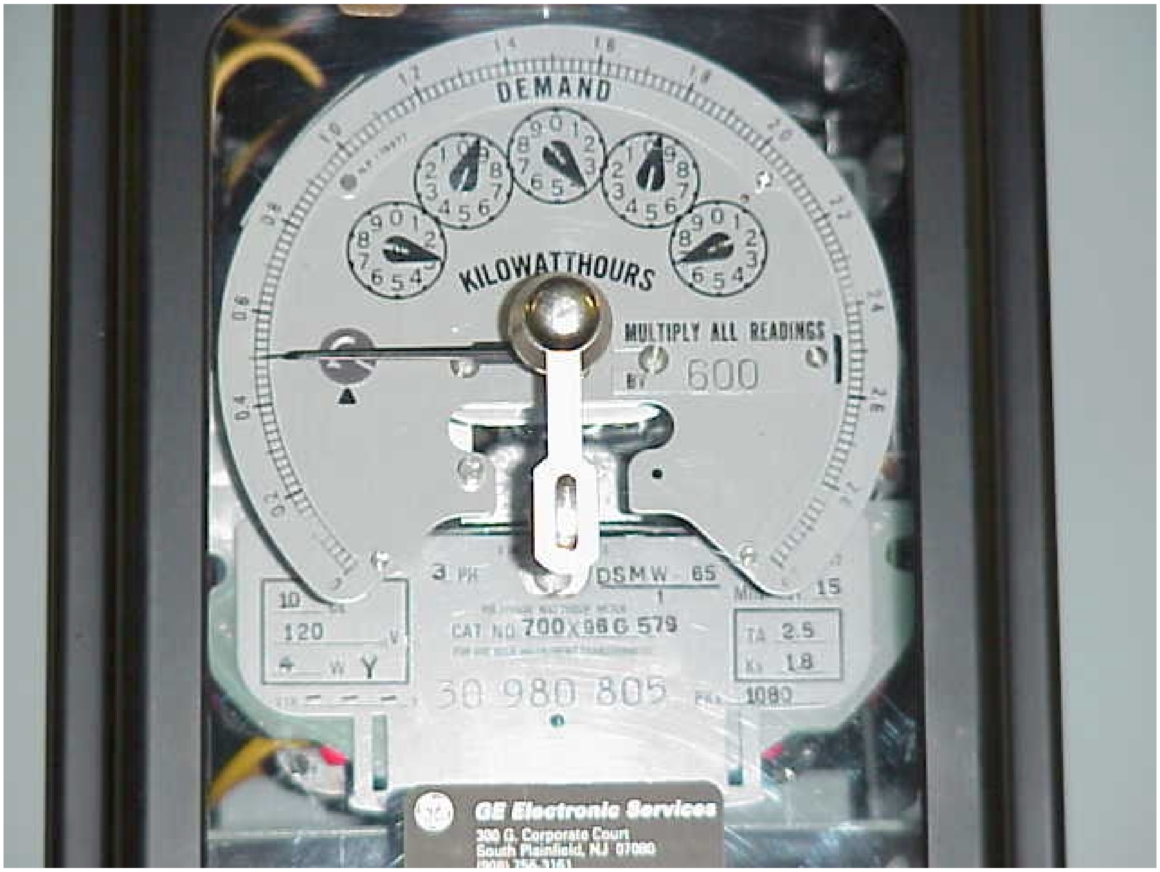
Load Center 6 – CDP 4-1, CDP 4-2, CDP 4-3, CP-7 kwh

The GE meter which was recording the power consumption on Load Center 6 was reading 29379 @ 15:45 on 8/21/02. The reading was 29397 @ 9am on 8/23/02. The total change in the meter consumption for the entire period was 18 units. The meter had a multiplication factor of 600 resulting in a total consumption of 10,800 kwh for the entire load center over 41 hours and 15 minutes. The average consumption for the load center was 4.36 kwh per minute or 6,284 kwh for a 24-hour period.

Subtracting the total consumption of CP-7 of 860 kwh for a 24-hour period yields a 24 hour consumption of 5,424 kwh for CDP 4-1, CDP 4-2 and CDP 4-3.

Installation Photograph - Load Center 6 Meter

The photograph below shows the ending value for the metering on Load Center 6.



Appendix C: Data Center References

ACEEE, and CECS. 2001. Funding prospectus for "Analysis of Data Centers and their implications for energy demand". Washington, DC, American Council for an Energy Efficient Economy (ACEEE); Center for Energy and Climate Solutions (CECS). July 2001.
The paper includes an overview of data centers; discusses energy use, energy choices, and energy efficiency in data centers; potential impacts of data centers; present and future regulatory issues; and business opportunities in energy services.

Aebischer, B., R. Frischknecht, C. Genoud, A. Huser, and F. Varone. 2002a. Energy- and Eco-Efficiency of Data Centres. A study commissioned by Département de l'intérieur, de l'agriculture et de l'environnement (DIAE) and Service cantonal de l'énergie (ScanE) of the Canton of Geneva, Geneva, November 15.
The study investigates strategies and technical approaches to fostering more energy-efficient and environmentally sound planning, building and operating of data centres. It also formulate recommendations on how to integrate the findings in the legal and regulatory framework in order to handle construction permits for large energy consumers and promote energy efficiency in the economic sectors. Seventeen recommendations grouped in four topics are derived from study conclusions: Transfer of the accord into an institutionalised legal and regulatory framework; Energy-efficiency policies for all large energy consumers; Preconditions, and prerequisites; Operational design of voluntary energy policies.

Aebischer, B., R. Frischknecht, C. Genoud, and F. Varone. 2002b. Energy Efficiency Indicator for High Electric-Load Buildings. The Case of Data Centres. <u>Proceedings of the IEECB 2002. 2nd International Conference on Improving Electricity Efficiency in Commercial Buildings</u>. Nice, France.
Energy per unit of floor area is not an adequate indictor for energy efficiency in high electric-load buildings. For data centres we propose to use a two-stage coefficient of energy efficiency CEE = C1 * c2, where C1 is a measure of the efficiency of the central infrastructure and c2 a measure of the energy efficiency of the equipment.

Anonymous. 2001. Model Data Center Energy Design Meeting. Austin Energy, Austin, TX, Feb 12-13.
http://www.austinenergy.com/business/energy_design_meeting.htm

Anonymous. 2002a. 7 x 24 Update: Design & Construction - Issues and trends in mission critical infrastructure design, planning and maintenance.
http://www.facilitiesnet.com/BOM/Jan02/jan02construction.shtml. July 23, 2002.
http://www.7x24exchange.org/.

Anonymous. 2002b. Continuous Availability Review (CAR). The Uptime Institute: Computersite Engineering, Inc. *http://www.upsite.com/csepages/csecar.html*. July 22, 2002.

Anonymous. 2002c. End-to-End Reliability Begins with the User's Definition of Success. The Uptime Institute. *http://www.upsite.com/TUIpages/editorials/endtoend.html*. July 22, 2002.

Anonymous. 2002d. Mechanical Systems Diagnostic Review (MSDR). The Uptime Institute: Computersite Engineering, Inc. *http://www.upsite.com/csepages/csemsdr.html*. July 22, 2002.

Anonymous. 2002e. Site Infrastructure Operations Review (SIOR). The Uptime Institute: Computersite Engineering, Inc. *http://www.upsite.com/csepages/cseior.html*. July 22, 2002.

Baer, D. B. Emerging Cooling Requirements & Systems in Telecommunications Spaces, Liebert Corporation.
During the last several years, power density trends, and consequently thermal density trends in telecommunications spaces have become topics of increasing interest. This paper identifies several of the underlying drivers of these trends, project possible outcomes, and assess the impact on cooling system design for these spaces.

Beck, F. 2001. Energy Smart Data Centers: Applying Energy Efficient Design And Technology To The Digital Information Sector. *Renewable Energy Policy Project (REPP): Washington, DC.* (November 2001 REPP).
Both utilities and data center owners face challenges in meeting electricity demand loads with required levels of reliability. However, the bursting of the high-tech stock bubble in 2000 and the 2001 U.S. economic downturn has slowed expansion of data centers. This provides time and an opportunity to examine data center construction and operational practices with an eye toward reducing their energy demands through use of energy efficient technologies and energy smart design practices. As the economy recovers and the next data center rush approaches, best practices can reduce energy use while maintaining or even increasing data center reliability. Energy demands of data centers that support the digital information- and communications-based economy need not be as high as some predict. In fact, data center power demands could be reduced by 20 percent with minimal efficiency efforts, and by 50 percent with more aggressive efficiency measures.

Blount, H. E., H. Naah, and E. S. Johnson. 2001. Data Center and Carrier Hotel Real Estate: Refuting the Overcapacity Myth. Lehman Brothers: TELECOMMUNICATIONS, New York, June 7, 2001. http://www.lehman.com
An exclusive study examining supply and demand trends for data center and carrier hotel real estate in North America. Lehman Brothers and Cushman &

Wakefield have completed the first in a regular series of proprietary studies on telecommunications real estate (TRE), including carrier hotels and data centers.

Bors, D. 2000. Data centers pose serious threat to energy supply. *Puget Sound Business Journal (Seattle) - October 9, 2000.* http://seattle.bizjournals.com/seattle/stories/2000/10/09/focus5.html
To cope with increasing energy demand from data centers, the author discussed feasibilities of two possible approaches: 1) energy industry approach by looking at alternative energy supply; 2) construction industry approach by looking at data center energy efficiency. To get there, it is worth investigating four distinct components. (I) Co-generation of power. Presently, standby diesel generators are required to maintain the desired level of reliability at most data center sites, but their exhaust makes most of these generators unacceptable for long-term power generation. (II) Fuel cells offer the promise of very clean emissions and the reasonable possibility for use as standby power. (III) Increased efficiency in data center power distribution systems. There are two separate items that are major contributors to data center power distribution system inefficiencies. The first, power distribution units (PDUs), are available with optional internal transformers that use less energy than the present cadre of K-rated transformers. The second, uninterruptible power systems (UPSs), come in a range of efficiency ratings. If the use of high-efficiency PDUs and UPSs are combined, they offer the potential of a 6 percent saving. (IV) Increased efficiency in mechanical cooling systems. In order to ensure data center reliability, mechanical equipment is often selected as a large number of small, self-contained units, which offers opportunities to improve efficiencies. (V) Reductions in energy use by computer, network and storage equipment. Computer manufacturers can do their part by creating computers with greater computational power per watt. They have been doing this for years as a side effect of hardware improvements, and they can do even better if they make it a goal.

Brown, E., R. N. Elliott, and A. Shipley. 2001. Overview of Data Centers and Their Implications for Energy Demand. Washington, DC, American Council for an Energy Efficient Economy, Center for Energy & climate Solutions (CECS). September 2001. http://www.aceee.org/pdfs/datacenter.pdf.pdf
The white paper discusses data center industry boom and energy efficiency opportunities and incentives in internet data centers. Emerging in the late 1990's, data centers are locations of concentrated Internet traffic requiring a high-degree of power reliability and a large amount of power relative to their square footage. Typically, power needs range from 10-40MW per building, and buildings are typically built in clusters around nodes in the Internet fiber-optic backbone. During the development boom in 1999 and 2000, projects averaged 6-9 months from site acquisition to operation, and planned operational life was 36 months to refit. Even high energy-prices were dwarfed by net daily profits of 1-2 million dollars per day for these buildings during the boom, creating little incentive for efficient use of energy.

Callsen, T. P. 2000. The Art of Estimating Loads. *Data Center* (Issue 2000.04).
This article discusses the typical Data Center layout. It includes floor plan analysis, HVAC requirements, and the electrical characteristics of the computer hardware typically found in a Data Center.

Calwell, C., and T. Reeder. 2002. Power Supplies: A Hidden Opportunity for Energy Savings (An NRDC Report). Natural Resources Defense Council, San Francisco, CA, May 22, 2002. http://www.nrdc.org
The article discusses the efficiency of power supplies which perform current conversion and are located inside of the electronic product (internal) or outside of the product (external). The study finds that most external models, often referred to as "wall-packs" or "bricks," use a very energy inefficient design called the linear power supply, with measured energy efficiencies ranging from 20 to 75%; that most internal power supply models use somewhat more efficient designs called switching or switch-mode power supplies; and that internal power supplies have energy efficiencies ranging from 50 to 90%, with wide variations in power use among similar products. Most homes have 5 to 10 devices that use external power supplies, such as cordless phones and answering machines. Internal power supplies are more prevalent in devices that have greater power requirements, typically more than 15 watts. Such devices include computers, televisions, office copiers, and stereo components. The paper points out that power supply efficiency levels of 80 to 90% are readily achievable in most internal and external power supplies at modest incremental cost through improved integrated circuits and better designs.

Cratty, W., and W. Allen. 2001. Very High Availability (99.9999%) Combined Heat and Power for Mission Critical Applications. *Cinintel 2001*: 12. http://www.surepowersystem.com

Elliot, N. 2001. Overview of Data Centers and their implications for energy demand. Washington, DC, American Council for an Energy Efficient Economy. Jan 2001, revised June 10, 2001.

Feng, W., M. Warren, and E. Weigle. 2002. The Bladed Beowulf: A Cost-Effective Alternative to Traditional Beowulfs. *Cluster2002 Program*. http://www-unix.mcs.anl.gov/cluster2002/schedule.html; public.lanl.gov/feng/Bladed-Beowulf.pdf
Authors present a novel twist to the Beowulf cluster - the Bladed Beowulf. In contrast to traditional Beowulfs which typically use Intel or AMD processors, the Bladed Beowulf uses Transmeta processors in order to keep thermal power dissipation low and reliability and density high while still achieving comparable performance to Intel- and AMD-based clusters. Given the ever increasing complexity of traditional super-computers and Beowulf clusters; the issues of size, reliability, power consumption, and ease of administration and use will be "the" issues of this decade for high-performance computing. Bigger and faster machines are simply not good enough anymore. To illustrate, Authors present the

results of performance benchmarks on the Bladed Beowulf and introduce two performance metrics that contribute to the total cost of ownership (TCO) of a computing system - performance/power and performance/space.

Frith, C. 2002. Internet Data Centers and the Infrastructure Require Environmental Design, Controls, and Monitoring. *Journal of the IEST* **45**(2002 Annual Edition): 45-52.
Internet Data Centers and the Infrastructure Require Environmental Design, Controls, and Monitoring. The author points out that specifications and standards need to be developed to achieve high performance for mission-critical internet applications.

Gilleskie, R. J. 2002. The Impact of Power Quality in the Telecommunications Industry. Palm Springs, CA, June 4. http://www.energy2002.ee.doe.gov/Facilities.htm
The workshop addresses the unique issues and special considerations necessary for improving the energy efficiency and reliability of high-tech data centers. This presentation addresses impacts of power quality including voltage sags, harmonics, and high-frequency grounding in telecommunication industry.

Grahame, T., and D. Kathan. 2001. Internet Fuels Shocking Load Requests. *Electrical World* **Vol. 215** (3): 25-27.
http://www.platts.com/engineering/ew_back_issues.shtml
This article discusses the implications of the increase for power demand by the Internet's traffic growth on utility planning, operation, and financing.

Greenberg, D. 2001. Addendum to ER-01-15: A Primer on Harmonics. E-SOURCE, Boulder, Colorado, September 2001.
The electrical distribution systems of most commercial and industrial facilities were not designed to operate with an abundance of harmonics-producing loads. In fact, it is only within recent years that such loads have become widespread enough for industry to take notice and to begin to develop strategies to address the problems that harmonics can create. By 1992, concern about the issue had grown sufficiently that the Institute for Electrical and Electronic Engineers (IEEE) developed and published its standard 519, "IEEE Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems," which established an approach for setting limits on the harmonic voltage distortion on the utility power system and on the harmonic currents created individual power consumers. Since that time, the electronic loads that give rise to harmonic currents have grown dramatically and are projected to continue growing for the foreseeable future. This being the case, there is and will continue to be a market for technological solutions to the problems that harmonics can cause.

Gross, P. 2002. Needed: New Metrics. *Energy User News*.
http://www.energyusernews.com/eun/cda/articleinformation/features/bnp__features__item/0,2584,82741,00.html

Gruener, J. 2000. Building High-Performance Data Centers. *Dell Magazines - Dell Power Solutions* (Issue 3 "Building Your Internet Data Center"). http://www.dell.com/us/en/esg/topics/power_ps3q00_1_power.htm; http://www.dell.com/us/en/esg/topics/power_ps3q00-giganet.htm
The introduction of Microsoft SQL Server 2000 is a milestone in the race to build the next generation of Internet data centers. These new data centers are made up of tiers of servers, now commonly referred to as server farms, which generally are divided into client services servers (Web servers), application/business logic servers, and data servers supporting multiple instances of databases such as SQL Server 2000.

Hellmann, M. 2002. Consultants Face Difficult New Questions in Evolving Data Center Design. *Energy User News*. http://www.energyusernews.com/CDA/ArticleInformation/features/BNP__Features__Item/0,2584,70610,00.html
While few data center design projects are alike, there are always the twin challenges of "power and fiber." And sometimes, even local politics and human factors. The paper suggested that the consultant should be brought in as soon as a business case is established so criteria can be established and a concept can be developed, priced, and compared to the business case. A planning is necessary before moving on to site selection and refine the concept and again test the business case.

Howe, B., A. Mansoor, and A. Maitra. 2001. Power Quality Guidelines for Energy Efficient Device Application - Guidebook for California Energy Commission (CEC). Final Report to B. Banerjee, California Energy Commission (CEC).
Energy efficiency and conservation are crucial for a balanced energy policy for the Nation in general and the State of California. Widespread adaptation of energy efficient technologies such as energy efficient motors, adjustable speed drives, improved lighting technologies will be the key in achieving self sufficiency and a balanced energy policy that takes into account both supply side and demand side measures. In order to achieve the full benefit of energy efficient technologies, these must be applied intelligently, and with clear recognition of the impacts some of these technologies may have on power quality and reliability. Any impediment to the application of these energy efficient technologies by the customers is not desirable for the overall benefit to energy users in California. With that in mind EPRI and CEC has worked to develop this guidebook to promote customer adaptation of energy efficient technologies by focusing on three distinct objectives. 1) Minimize any undesirable power quality impacts of energy-saving technologies; 2) Understand the energy savings potential of power quality-related technologies. These include: Surge Protective Devices (SPDs) or Transient Voltage Surge Suppressors (TVSS), Harmonic Filters, Power Factor Correction Capacitors, Electronic Soft Starters for Motors; and 3) How to evaluate "black box" technologies

Intel. 2002. Planning and Building a Data Center - Meeting the e-Business Challenge. Intel Corp. *http://www.intel.com/network/idc/doc_library/white_papers/data_center/*. Aug 01, 2002.
The paper discusses the keys to success of Internet Service Providers (ISPs) that include 1) Achieve the economies of scale necessary to support a low price business model; 2) Offer added value, typically in the form of specialized services such as applications hosting to justify a premium price. This document provides a high-level overview of the requirements for successfully establishing and operating an Internet data center in today's marketplace. It offers some of the key steps that need to be taken, including project definition, prerequisites and planning. In order to construct a data center that can meet the challenges of the new market, there are three basic areas of data center definition and development: 1) Facilities: including building, security, power, air-conditioning and room for growth; 2) Internet connectivity: performance, availability and scalability; 3) Value-added services and the resources to support their delivery: service levels, technical skills and business processes. The aim is to provide customers with the physical environment, server hardware, network connectivity and technical skills necessary to keep Internet business up and running 24 hours a day, seven days a week. The ability to scale is essential, allowing businesses to upgrade easily by adding bandwidth or server capacity on demand.

Koplin, E. 2000. Finding Holes In The Data Center Envelope. *Engineered Systems* (September 2000). http://www.esmagazine.com/CDA/ArticleInformation/features/BNP__Features__Item/0,2503,8720,00.html
The paper addresses importance of environmental control in data center facilities. Maintaining data center availability requires absolutely reliable infrastructure. A significant amount of this is devoted solely to maintaining stable environmental parameters. And only constant, thorough regulation and testing of these parameters ensures the integrity of the data center “envelope.”

Mandel, S. 2001. Rooms that consume - Internet hotels and other data centers inhale electricity. *Electric Perspectives* **Vol. 26** (No.3). http://www.eei.org/ep/editorial/Apr_01/0401ROOM.htm
The article estimated that the amount of this data center space in the United States nearly doubled in 2000, totaling between 19 million and 25 million square feet by year-end, according to investment analysts. They say they expect another 10 million to 20 million square feet of new space to be added in 2001. Developers are asking electric utilities to supply the buildings with 100-200 watts of electricity per square foot. Since these data centers are new to the economy, there is little historical data on which to base estimates of electricity use for a facility. In addition, the dot.com world makes it difficult for the developer to say confidently how much electricity one of these internet hotels will use. Source One estimates that tens of billions of dollars worth of electric infrastructure improvements will be needed for data centers over the next few years and that

they will consume billions of dollars more worth of electricity. The energy costs are as high or higher than the actual lease costs. Indeed, 50-60 percent of the cost of building a data center is for the power, including batteries, backup generators, and air-conditioning, as well as the cost for utility construction.

Mitchell-Jackson, J. 2001. Energy Needs in an Internet Economy: A Closer Look at Data Centers, July, 2001.
This study explains why most estimates of power used by data centers are significantly too high, and gives measured power use data for five such facilities. Total power use for the computer room area of these data centers is no more than 40 W/square foot, including all auxiliary power use and cooling energy. There are two draft journal articles from this work, one focusing on the detailed power use of the data center we've examined in most detail, and the other presenting the aggregate electricity use associated with hosting-type data centers in the U.S.

Mitchell-Jackson, J., J. G. Koomey, B. Nordman, and M. Blazek. 2001. Data Center Power Requirements: Measurements From Silicon Valley. *Energy—the International Journal (Under review).*
http://enduse.lbl.gov/Projects/InfoTech.html
Current estimates of data center power requirements are greatly overstated because they are based on criteria that incorporate oversized, redundant systems, and several safety factors. Furthermore, most estimates assume that data centers are filled to capacity. For the most part, these numbers are unsubstantiated. Although there are many estimates of the amount of electricity consumed by data centers, until this study, there were no publicly available measurements of power use. This paper examines some of the reasons why power requirements at data centers are overstated and adds actual measurements and the analysis of real-world data to the debate over how much energy these facilities use.

Patel, C. D., C. E. Bash, C. Belady, L. Stahl, and D. Sullivan. 2001. Computational Fluid Dynamics Modeling of High Compute Density Data Centers to Assure System Inlet Air Specifications. Reprinted from the proceedings of the Pacific Rim ASME International Electronic Packaging Technical Conference and Exhibition (IPACK 2001), © 2001, ASME.
Due to high heat loads, designing the air conditioning system in a data center using simple energy balance is no longer adequate. Data center design cannot rely on intuitive design of air distribution. It is necessary to model the airflow and temperature distribution in a data center. This paper presents a computational fluid dynamics model of a prototype data center to make the case for such modeling.

Patel, C. D., R. Sharma, C. E. Bash, and A. Beitelmal. 2002. Thermal Considerations in Cooling Large Scale High Compute Density Data Centers. 8th ITHERM Conference. San Diego CA.
A high compute density data center of today is characterized as one consisting of thousands of racks each with multiple computing units. The computing units

include multiple microprocessors, each dissipating approximately 250 W of power. The heat dissipation from a rack containing such computing units exceeds 10 KW. Today's data center, with 1000 racks, over 30,000 square feet, requires 10 MW of power for the computing infrastructure. A 100,000 square foot data center of tomorrow will require 50 MW of power for the computing infrastructure. Energy required to dissipate this heat will be an additional 20 MW. A hundred thousand square foot planetary scale data center, with five thousand 10 KW racks, would cost ~$44 million per year (@ $100/MWh) just to power the servers & $18 million per year to power the cooling infrastructure for the data center. Cooling design considerations by virtue of proper layout of racks can yield substantial savings in energy. This paper shows an overview of a data center cooling design and presents the results of a case study where layout change was made by virtue of numerical modeling to avail efficient use of air conditioning resources.

PG&E. 2001. Data Center Energy Characterization Study. Pacific Gas and Electric Company (subcontractor: Rumsey Engineers), San Francisco, Feb. 2001. Rumsey Engineers, Inc. and PG&E have teamed up to conduct an energy study as part of PG&E's Data Center Energy Characterization Study. This study will allow PG&E and designers to make better decisions about the design and construction of data centers in the near future. Three data centers in the PG&E service territory have been analyzed during December 2000 and January 2001, with the particular aim of determining the end-use of electricity. The electricity use at each facility was monitored for a week each. At the end of the report are a set of definitions, which explain the terms used and the components in making each calculation. The three data centers provide co-location service, which is an unmanaged service that provides rack space and network connectivity via a high capacity backbone. About half or more of the electricity goes to powering the data center floor, and 25 to 34 percent of the electricity goes to the heating, air conditioning and ventilation equipment. The HVAC equipment uses a significant amount of power and is where energy efficiency improvements can be made. All three facilities use computer room air conditioning (CRAC) units, which are stand-alone units that create their own refrigeration and circulate air. A central, water-cooled chilled water system with air handlers and economizers can provide similar services with roughly a 50% reduction in cooling energy consumption. Energy density of the three buildings had an average of 35 W/sf. The cooling equipment energy density for the data center floor alone averaged at 17 W/sf for the three facilities. The average designed energy density of the three data centers' server loads was 63 W/sf, while the measured energy density was 34 W/sf. An extrapolated value was also calculated to determine what the server load energy density would be when fully occupied. The average extrapolated energy density was 45 W/sf. Air movement efficiency varies from 23 to 64 percent between the three facilities. Cooling load density varies from 9 to 70 percent between the three facilities.

Planet-TECH. 2002. Technical and Market Assessment for Premium Power in Haverhill. Planet-TECH Associates for The Massachusetts Technology Collaborative,

www.mtpc.org, Westborough, MA 01581-3340, Revision: February 20, 2002. http://www.mtpc.org/cluster/Haverhill_Report.pdf ; http://www.planet-tech.com/content.htm?cid=2445
This study is pursued under contract to the Massachusetts Technology Collaborative, in response to a request for a "Technical and Market Assessment". It seeks to determine if the provisioning of "premium power" suitable for data-intensive industries will improve the marketability of a Historic District mill building in Haverhill. It is concluded that such provisioning does improve the marketability, however, not to a degree that is viable at this time. Other avenues for energy innovation are considered and recommendations for next steps are made.

RMI, and DR International. 2002. Energy Efficient Data Centers - A Rocky Mountain Institute Design Charrette. Organized, Hosted and Facilitated by Rocky Mountain Institute, with D&R International, Ltd. and Friends. Hayes Mansion Conference Center, San Jose, California.
Rapid growth of "mission critical" server-farm and fiber-optic-node data centers has presented energy service providers with urgent issues. Resulting costs have broad financial and societal implications. While recent economic trends have severely curtailed projected growth, the underlying business remains vital. The current slowdown allows us all some breathing room—an excellent opportunity to step back and carefully evaluate designs in preparation for surviving the slowdown and for the resumption of explosive growth. Future data center development will not occur in the first-to-market, damn-the-cost environment of 1999-2000. Rather, the business will be more cost-competitive, and designs that can deliver major savings in both capital cost (correct sizing) and operating cost (high efficiency)—for both new build and retrofit—will provide their owners and operators with an essential competitive advantage.

Robertson, C., and J. Romm. 2002. Data Centers, Power, and Pollution Prevention - Design for Business and Environmental Advantage. The Center for Energy and Climate Solutions; A Division of The Global Environment and Technology Foundation, June 2002. http://www.cool-companies.org; http://www.getf.org
Computers and other electronic equipment will crash at the slightest disruption or fluctuation in their supply of electricity. The power system was not designed for these sensitive electronic loads and is inherently unable to meet the technical requirements of the information economy. For data centers, which play a central role in the information economy, crashing computers cause potentially catastrophic financial losses. The same voltage sag that causes the lights to dim briefly can cause a data center to go off-line, losing large sums of money, for many hours. Data center owners and their power providers must therefore solve several related technical and economic electric power problems. These are: 1) How to assure high-availability (24x7) power supply with a very low probability of failure; 2) How to assure practically perfect power quality; and 3) How to manage risk while minimizing capital and operating expenses

Roth, K. W., Fred Goldstein, and J. Kleinman. 2002. Energy consumption by office and telecommunications equipment in commercial buildings, Volume I: Energy Consumption Baseline. Arthur D. Little (ADL), Inc., 72895-00, Cambridge, MA, January 2002.

ADL carried out a "bottom-up" study to quantify the annual electricity consumption (AEC) of more than thirty (30) types of non-residential office and telecommunications equipment. A preliminary AEC estimate for all equipment types identified eight key equipment categories that received significantly more detailed studied and accounted for almost 90% of the total preliminary AEC. The Key Equipment Categories include: *Computer Monitors and Displays, Personal Computers, Server Computers , Copy Machines, Computer Network Equipment, Telephone Network Equipment, Printers, Uninterruptible Power Supplies (UPSs).* The literature review did not uncover any prior comprehensive studies of telephone network electricity consumption or uninterruptible power supply (UPS) electricity consumption. The AEC analyses found that the office and telecommunications equipment consumed 97-TWh of electricity in 2000. The report concludes that commercial sector office equipment electricity use in the U.S. is about 3% of all electric power use. The ADL work also creates scenarios of future electricity use for office equipment, including the energy used by telecommunications equipment.

Sullivan, R. F. 2002. Alternating Cold and Hot Aisles Provides More Reliable Cooling for Server Farms. The Uptime Institute. http://www.uptimeinstitute.org/tuiaisles.html

The creation of "server farms" comprising hundreds of individual file servers has become quite commonplace in the new e-commerce economy, while other businesses spawn farms by moving equipment previously in closets or under desktops into a centralized data center environment. However, many of these farms are hastily planned and implemented as the needed equipment must be quickly installed on a rush schedule. The typical result is a somewhat haphazard layout on the raised floor that can have disastrous consequences due to environmental temperature disparities. Unfortunately, this lack of floor-layout planning is not apparent until after serious reliability problems have already occurred.

The Uptime Institute. 2000. Heat-Density Trends in Data Processing, Computer Systems, and Telecommunications Equipment. The Uptime Institute, Version 1.0., http://www.upsite.com/. http://www.uptimeinstitute.org/heatdensity.html

This white paper provides data and best available insights regarding historical and projected trends in power consumption and the resulting heat dissipation in computer and data processing systems (servers and workstations), storage systems (DASD and tape), and central office-type telecommunications equipment. The topics address the special needs of Information Technology professionals, technology space and data center owners, facilities planners, architects, and engineers.

Thompson, C. S. 2002. Integrated Data Center Design in the New Millennium. *Energy User News*. http://www.energyusernews.com/CDA/ArticleInformation/features/BNP__Features__Item/0,2584,70578,00.html
Data center design requires planning ahead and estimating future electrical needs. Designers must accurately predict space and energy requirements, plus cooling needs for new generations of equipment. Importance of data center reliability is discussed.

Wood, L. 2002. Cutting Edge Server Farms - The blade server debate. newarchitectmag.com. *http://www.newarchitectmag.com/documents/s=2412/na0702f/index.html*. July 23, 2002. A blade is the industry term for a server that fits on a single circuit board, including CPU, memory, and perhaps a local hard disk. Multiple blades are plugged into a chassis, where each blade shares a common power supply, cooling system, and communications back plane. Multiple chassis can then be stacked into racks. By comparison, the conventional approach for rack-mounted servers involves only one server per chassis. A chassis cannot be smaller than one vertical rack unit (1U, or about 1.75 inches high). This limits you to 42 to 48 servers in a standard seven-foot rack. A typical blade chassis is much higher than 1U, but several can still be stacked in a rack, allowing upwards of 300 servers per rack, depending on the vendor and configuration. This compact design offers compelling advantages to anyone operating a high-density server farm where space is at a premium. Indeed, blades are the "next big thing" in servers, and it's probable that any given administrator will have to decide whether to adopt them in the near future.